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VERIFICATION AND VALIDATION OF THE MARINE CORPS MODERNIZED RECRUIT DISTRIBUTION MODEL (M-RDM)

by

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June 2022

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The task of assigning a Marine Corps recruit to a military occupational specialty (MOS) while scheduling them for the requisite corresponding initial training course is nontrivial when aggregated over an entire fiscal year (FY). Despite fluctuations in the skills and interests of the recruits who complete boot camp approximately weekly, it is important that these assignments balance the minimum skill requirements and FY target quotas for each MOS, while also minimizing the amount of time that a recruit waits idle to attend the needed training.

The recently developed Marine Corps Modernized Recruit Distribution Model (M-RDM) may represent a significant leap forward in capability for the stakeholder agency, Marine Corps Manpower Management and Integration Branch (MMIB). Unfortunately, MMIB lacks the necessary verification, validation, and user interface for the new model to feel confident employing it solely in place of the aging legacy Recruit Distribution Model (RDM).

This thesis presents a side-by-side comparison of the RDM results attained in FY19 alongside those that would have been attained with the M-RDM, given the same input information. It also proposes several improvements to the M-RDM intended to provide greater flexibility and improved "goodness of fit" for assigned Marines.

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List of Acronyms and Abbreviations

ACP annual classification plan

ADVANA advanced analytics

AMOS additional MOS

ASVAB Armed Services Vocational Aptitude Battery

CID course identification code

CL clerical category

SARS-CoV-2 Severe Acute Respiratory Syndrome Coronavirus 2

COVID-19 coronavirus disease 2019

CSS combat service support

CY calendar year

DC deputy commandant

EAB Expeditionary Advanced Base

EABO Expeditionary Advanced Base Operations

EAMTMU Enlisted Aviation Maintenance Trainee Management Unit

EDIPI electronic data interchange-personal identifier

EL electrical category

ESM Enhanced Shipping Model

FLC fleet learning center

Fortran Formula Translator

FTAP First Term Alignment Plan

FY fiscal year

GoF “goodness of fit”

GT general technical category

GUI graphical user interface

HRDP human resources development process

IDE interactive development environment

IMOS initial MOS

ITB Infantry Training Battalion

MAT “Marine awaiting training”

MCOSM Marine Corps Occupational Specialty Matching

MCRC Marine Corps Recruiting Command

MCRD Marine Corps Recruit Depot

MCRISS II Marine Corps Recruiting Information Support System II

MCRP Marine Corps Reference Publication

MCS Marine combat standards

MCSC Marine Corps Systems Command

MCT Marine Combat Training Battalion

MCTFS Marine Corps Total Force System

MCTIMS Marine Corps Training Information Management System

MCTP Marine Corps Techniques Publication

MEF Marine Expeditionary Force

MEPS Military Entrance Processing Station

MIT Manpower Information Technology

MM mechanical maintenance category

MMIB Manpower Management Integration Branch

MMIB-2 Force Augmentation Section

MOI metric of interest

MOIs metrics of interest

MOS military occupational specialty

MP Manpower Plans and Policy Division

MPA Manpower Studies and Analysis

MPP Manpower Plans Programs and Budget Branch

MPP-20 Enlisted Plans Section

M&RA Manpower and Reserve Affairs

M-RDM Modernized Recruit Distribution Model

M-RDM-22 "Modernized Recruit Distribution Model (M-RDM) 2022"

M-RDM-22a "M-RDM 2022 Alpha"

M-RDM-22b "M-RDM 2022 Bravo"

NMCI Navy/Marine Corps Intranet

NPS U.S. Naval Postgraduate School

OCC occupational career code

ODSE Operational Data Store Enterprise

P2T2 patients, prisoners, trainees, and transients

PEF	"program enlisted for"
PMOS	primary MOS
PRASP	Permissive Recruiters Assistance Program
P&R	Programs and Resources
RDM	Recruit Distribution Model
SOI	School of Infantry
STF	"street-to-fleet"
TAD	temporary additional duty
TCSI	The Consolidated Systems Integrator
TECOM	Training and Education Command
TFDW	Total Force Data Warehouse
TSO	Technology Services Organization
UD/MIPS	Unit Diary/ Marine Integrated Personnel System
U.S.	United States
USMC	U.S. Marine Corps
USN	U.S. Navy

Executive Summary

During each fiscal year the Marine Corps must determine the primary military occupational specialty (PMOS) into which to classify tens of thousands of entry-level active-duty enlisted recruits that join their ranks as they graduate from the recruit depots. They must do so, if possible, in a manner that does not violate each recruit's "program enlisted for" (PEF) contract, assuming the recruit fulfills all the associated minimum standards for their contracted PEF while at the recruit depot. Concurrently with selecting them for an appropriate PMOS, the Marine Corps must also determine the initial course offering to send those Marines to for follow-on training, after allowing them to take the initial "boot leave" they have earned and allowing time for them to complete their required basic combat training. An assignment for each of these recruits is then considered to include three elements: a recruit, their assigned PMOS, and their initial course offering.

Collectively, these assignments, after first being checked for feasibility based on recruit scores, PEF requirements, and projected course offerings for the coming fiscal year, may be considered favorable or unfavorable based on a number of common-sense metrics. The first, would be the question of how many of the Marine Corps' stated fiscal year accession cohort production requirements for each PMOS are satisfied by the assignments, and how many are left short. The second key evaluator of the assignments is the so-called "goodness of fit" between a given recruit and their assigned PMOS. This metric for each Marine has the potential to impact not only their future job performance, but also their propensity to re-enlist at key milestones throughout their career if they are placed into a PMOS that is both appropriately challenging for them and of sufficient interest to them. The third commonly considered metric is that of the expected "Marine awaiting training" (MAT) time that will be incurred by each of the assignments. This metric attempts to capture the cost in days of assigning recruits into courses that do not occur near simultaneously with the completion of their basic combat training.

Currently, to make such assignments the Marine Corps relies on the Recruit Distribution Model (RDM), which has been working adequately for years, but which is singly focused on reducing end-of-year PMOS classification shortages. The RDM uses expected MAT times only as an afterthought and tie-breaker for assignment determination, and does not consider “goodness of fit” (GoF) at all beyond the basic determination of MOS eligibility.

This thesis extends previous work on a newly proposed Modernized Recruit Distribution Model (M-RDM), which takes a more holistic look at optimizing recruit assignments across the three primary metrics described above. The M-RDM also additionally considers the metric of MOS assignment overages (which it works to minimize in addition to minimizing those of the MOS shortfalls). It takes the existing M-RDM, which was validated only on a single graduation run in fiscal year 2021, and expands that model into one that can be used to automatically solve for an entire year of recruit depot graduating class assignments at the start of the fiscal year, given appropriate information on the recruits, available course offerings, and classification targets for each PMOS within each recruit depot graduating class.

This thesis presents a side-by-side comparison of the RDM results attained in FY19 alongside those that would have been attained with the M-RDM, given the same input information. As a basis for comparison, we consider 20,720 recruits spread across 36 historical graduation classes that comprise the fiscal year (FY)19 “accession cohort.” In addition, we start with 2,114 separate historical course offerings with (non-zero) availability. The model also takes as input the MOS classification target numbers for each of the 146 PMOSs within each of the 36 graduation classes. Unfortunately, the historical target numbers used in FY19 were not available, so these target values had to be generated from adjacent manpower model called the Enhanced Shipping Model (ESM). However, the ESM was first developed in FY20, thus requiring that we make several assumptions to get that model to work for FY19. The result is an imperfect basis for historical comparison, but the best possible given available data.

Our results reveal the relative strengths and weaknesses of the two compared models across the main three metrics of interest. The RDM, not surprisingly, performs very well in the area of minimizing MOS overall annual classification shortfalls, as that is really the single main objective of its formulation. The M-RDM by contrast, performs much better in the areas of both GoF and the expected MAT time of the assignments it makes. Specifically, the historical assignments by the RDM yielded an average expected MAT of 28.8 days, whereas the M-RDM yielded a MAT of only 14.7 days per recruit. *If these per-recruit savings of 14.1 days per recruit had been applied to all the 15,914 recruits that were classed by the* *simulated M-RDM model run in FY19, the difference would have amounted to about 615 recruit-years which, assuming appropriate "base pay" measures, could potentially have saved the Marine Corps $11,475,900 in FY19 for recruit base pay alone!*

This thesis also proposes several enhancements to the M-RDM intended to provide greater flexibility and improved “goodness of fit” for assigned Marines. In addition, this thesis presents two additional rigorous mathematical formulations for how to solve this problem of annual recruit assignments that hold promise for even more improvement in solutions.

This thesis supports broader talent management initiatives outlined by Commandant Berger to help mature the force to win in the anticipated future Expeditionary Advanced Based Operations (EABO) environment. Through incorporating a greater emphasis on GoF in model assignments it has the potential to improve first-term retention rates and cut down on the required number of personnel that need to be recruited and trained each year to maintain an appropriately shaped and more mature force structure.

This thesis also supports the migration to the use of the ADVANA/Jupiter cloud-based computing and analytics environment recently mandated by the Department of Defense and Department of the Navy, in that the newly proposed M-RDM is written in a more modern and flexible programming language that could more easily be incorporated into that environment than the programming language of the current model.

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And lastly, to Captain Tate Husemann, my fellow NPS operations analysis student who was trusting and supportive enough to offer me the use of his personal laptop in my garage for the final two weeks of my thesis work. You can tell who your true friends are when your laptop decides to blow a fan bearing and start squealing like a banshee, and potentially overheating to the point of self-destruction, during the final days of your thesis odyssey.

CHAPTER 1:
Introduction

In order to meet the ongoing personnel needs of the USMC, the Marine Corps Recruit Depots (MCRDs) graduate approximately 31,000 Marine recruits annually from their locations in Parris Island and San Diego (Berger 2021). Upon graduation, each recruit is assigned to an initial military occupational specialty (MOS) (IMOS) and is then scheduled for follow-on training to actually earn that primary MOS (PMOS) before being assigned to their first unit.

As the saying goes "every Marine is a rifleman;" however, there is considerable diversity in the tasks and skills required for each MOS, and it is important that recruits are assigned to an appropriate MOS for a variety of reasons. The first reason is performance—having the right person in the right job makes a unit more effective at what it does. A second reason is retention—a Marine who enjoys their work is more likely to re-enlist. However, there are a number of practical constraints on MOS assignment, imposed by the needs of the Marine Corps.

- *Minimum skill requirements.* There are minimum aptitude and/or proficiency requirements that must be met for a recruit to be assigned a given MOS.
- *Quotas.* Manpower models project needs and provide personnel targets for each MOS that must be met.
- *Training schedule.* Courses for each specialty are offered only periodically and are defined by a course identification code (CID) that specifies the course date, location, and sponsoring armed service. There are only a limited number of "seats" available in each course, and to meet quota targets it is important that each course is filled.
- *Recruit waiting times.* After a Marine graduates from Marine Combat Training Battalion (MCT), they are entitled to six weeks of leave before beginning an MOS training course. However, this leave may be extended beyond six weeks depending on the timing of the MOS training course and the Marine's completion of MCT. Long delays are costly for the Marine Corps and can even cause Marines to become disenfranchised with their career choice. Thus, the delay between MCT and MOS should be as close to six weeks as possible (United States Marine Corps 2018).

The Manpower Management Integration Branch (MMIB), working on behalf of the USMC deputy commandant (DC) for Manpower and Reserve Affairs (M&RA), has the difficult task of assigning an initial MOS and first training pipeline course CID to Marine recruits who graduate from MCRD Parris Island or MCRD San Diego over approximately 100 recruit series graduations spread throughout the year (Berger 2021). Some recruits sign a "program enlisted for" (PEF) contract while at Military Entrance Processing Station (MEPS). This contract guarantees they will later receive an MOS from among a specific grouping of related MOSs (assuming they are qualified for at least one such MOS). These recruits may be officially assigned their specific IMOS from within their PEF as early as a couple of weeks prior to their MCRD graduation, or as late as during their first required course in their assigned MOS pipeline (United States Marine Corps 2018).

An assignment of Marine recruits to MOSs and CIDs is favorable if it balances the need to meet annual fiscal year target numbers of each enlisted PMOS and it assigns recruits an IMOS that falls within their assigned PEF. If a recruit falls short of the minimum testing or training standards for all the PMOSs within their PEF, then MMIB needs to reclassify the recruits to any available PMOS within the USMC for which they are qualified. If someone is recruited as an "open contract" (i.e., with no assigned PEF), then this reclassification also needs to happen. This IMOS assignment must occur while balancing the need to fill MOSs that are a priority to the USMC first with the need to minimize the time that those recruits will have to wait to start the first school in their required training pipeline.

1.1 Why is this Problem Important?

Choosing the right assignments for recruit series graduations is important because it has long-term effects across the entire USMC. The three primary positive effects considered by M&RA operations analysts (and specifically examined in this thesis) include the following.

1. Reduced "Marine awaiting training" (MAT) time indicating a shortened expected time per recruit from the time of their post-MCT leave to the time they begin their first formal training school in their required MOS training pipeline (i.e., the start of their model-assigned CID).
2. More rapidly meeting the "needs of the Marine Corps" throughout the year on-average, (i.e., filling specific PMOS quotas for each recruit graduation class with

appropriate IMOSs in a timely fashion throughout the year).

3. Achieving the best possible "goodness of fit" (GoF) over the course of a year between Marines and their assigned MOS, where GoF is meant to capture both a Marine's aptitude for, and interest alignment with, a specific MOS. These factors together are expected to be positively correlated with a Marine's long-term success in the Marine Corps.

There are also several expected secondary positive effects of good MOS assignments:

1. By achieving a better overall GoF between Marines and their assigned MOS, it is expected those Marines will perform better for their future units within the Marine Corps. As the Commandant says in *Talent Management 2030*, "matching talents to duties maximizes performance" (Berger 2021, p. 4).
2. By reducing a Marine's MAT time they are less likely to become disenfranchised with the Marine Corps while living in a holding status in a transient barracks after completing their recruit training and before starting their first MOS training school, thereby better "sustaining the transformation" of motivated young recruits into effective and inspired Marines at their first duty stations, in accordance with Marine Corps Techniques Publication (MCTP) 6-10A.
3. By achieving a better GoF between a Marine and their assigned MOS it is expected that the Marine at the end of their first term will be more likely to re-enlist for a second. Currently, the Commandant says the Marine Corps is seeing approximately 75 percent of first-term Marines getting out at the end of their first term (Berger 2021). This places herculean annual requirements on Marine Corps Recruiting Command (MCRC) and on the recruit depots, School of Infantry (SOI), and entry-level schools headquartered by Training and Education Command (TECOM) to continuously recruit and train new replacements for all the first term Marines that are not reenlisting. The current requirement placed on recruiting stations is to bring in approximately 36,000 new recruits each year from across the country, in part to replace those that leave at the end of their first term (Berger 2021). Reducing this number would allow either a reduction in recruiting station billets or would enable recruiters in those existing billets to focus more of their attention on recruiting fewer, better candidates who will be more likely to serve for multiple enlistments. Retaining trained Marines is also considerably less costly than recruiting and training new ones.

4. By achieving a better GoF we can also help mature the force. In *Talent Management 2030*, the Commandant outlines three main benefits we can expect from a more mature Marine Corps:
    - *A more physically fit Marine Corps.* Contrary to popular belief, "Marines in their mid-to-late twenties do more pull-ups, crunches, ammunition can lifts, and run faster than Marines aged 17-22 (those typically in their first enlistments)" (Berger 2021).
    - *Better cognitive function and improved decision-making in aggregate from our Marines.* According to the Commandant, "Maturing the force by retaining a greater percentage of qualified first-term Marines will improve decision-making, problem solving, and risk assessment among our junior leaders, with immediate positive effects on our performance in competition and combat" (Berger 2021).
    - *Increased readiness of our warfighting units and stability across our Marine Expeditionary Forces (MEFs) (Berger 2021).* This is the expected result of reducing the currently dramatic swings in personnel readiness that infantry battalions frequently experience due to mass departures of first-term Marines, and the need to then start the unit training cycle over with their younger, "greener" replacements.

1.2 How is this Problem Currently Solved?

This problem is currently being solved by the Recruit Distribution Model (RDM), initially completed on 23 March 2012 and written in the programming language Formula Translator (Fortran) which is almost 40 years old (The Consolidated Systems Integrator (TCSI), MODELS 2020). Unfortunately, the RDM consistently produces infeasible Marine/MOS assignments that require a significant amount of human time to catch and then manually reclassify. Then the RDM is run again, and its results must again be manually checked for feasibility. The current staff of the MMIB are spending considerable time on tasks that would be better automated.

The primary metric minimized by the legacy RDM model is MAT, so a minimally-qualified Marine will be assigned into the first available MOS with a CID that has student seats available. The current RDM does not attempt to balance Marine MOS assignments with any sort of GoF measure for how likely a Marine is to succeed and be retained in the specific MOS to which they are assigned. As better talent management has been identified as a priority by the Commandant in his planning guidance (Berger 2019, 2021), GoF should definitely be incorporated in the assignment process.

In a recent U.S. Naval Postgraduate School (NPS) thesis titled "A Modernized Recruit Distribution Model," Martinez (2021) developed the Modernized Recruit Distribution Model (M-RDM), an optimization model that enables MMIB model users to flexibly weight the relative importance of three primary assignment objectives:

1. Prioritizing "needs of the Marine Corps" in terms of minimizing the number of target MOS quotas for the graduating class that are *unfilled*.
2. Reducing expected MAT time.
3. Maximizing GoF of recruits with their assigned MOSs.

The resulting objective function value is subject to several constraints:

- Every recruit must be assigned a CID offering.
- The number of recruits assigned to a particular CID offering cannot exceed the number of seats available.

The M-RDM gives MMIB modelers more flexibility in its application and likely represents an improvement over previous solutions to this problem. However to date M&RA has not officially adopted it. This is due, in part, because M&RA lacks the confidence in its results. More practically, the M-RDM lacks an appropriate graphical user interface for the enlisted staff sergeant modeler to efficiently use it and keep up with the operational tempo of recruit series graduations and required IMOS assignments. Thus, M&RA continues to run only the existing RDM at this time. M&RA needs convincing evidence to determine which model performs better (for their desired use case) over the course of an entire fiscal year of recruit/MOS assignments.

1.3 What Are We Doing to Solve the Problem?

Building on the past work of Martinez (2021) and based on the recommendation of current operations analysts at M&RA, the primary contribution of this thesis is a comparison of the newly proposed M-RDM model with the actual results that were achieved using the current RDM using historical data from fiscal year (FY) 2019. Of note, FY 2019 was recommended by M&RA to avoid manning abnormalities that occurred in FY 2020 and FY 2021 due to the coronavirus disease 2019 (COVID-19) pandemic. Having agreed with the stakeholder agency (MMIB) to proceed with the three primary measures of effectiveness listed above, we use all FY 2019 data available on the RDM runs that were conducted that year to inform us of the needed human data and the training seats that were available for all needed entry-level training courses, before then allowing the model results to diverge from there.

In the case of the M-RDM, we maintain master lists of available course offerings and seats, as well as recruits that have already been assigned throughout the fiscal year, to properly integrate those aspects from one MCRD graduation run to the next.

At the end of the simulated fiscal year we use appropriate tools to visualize the outcomes across the primary metrics of interest (MOIs) for the chief decision-makers at M&RA to easily compare and contrast the two models over the course of the entire FY, and we also highlight the key differences in the results for their review.

1.4 Defining Success

We will know we have succeeded in this thesis work when we have presented the primary stakeholder MMIB within M&RA with clear and convincing visual evidence of a comparison of a whole FY's worth of data so they can confidently determine which model, the RDM or the M-RDM, better suits the needs of the Marine Corps and which should eventually be discontinued.

CHAPTER 2:
Background

This chapter is intended to get the reader up-to-speed on everything they need to know about the manpower process of making enlisted Marines and assigning each an MOS. It provides a brief snapshot and explanation of the overall process, then a bit of a deeper dive into the RDM currently in use as well as its strengths and weakness. We will also discuss the M-RDM developed by Captain Ryan Martinez in 2021, including the advances of that model as well as areas where there is remaining room for improvement. This will help put the contributions of this thesis, discussed in Chapter 3, into better context.

2.1 The Manpower Process for Making Enlisted Marines

The manpower and training process for creating fully trained Fleet-ready Marines looks something like Figure 2.1.

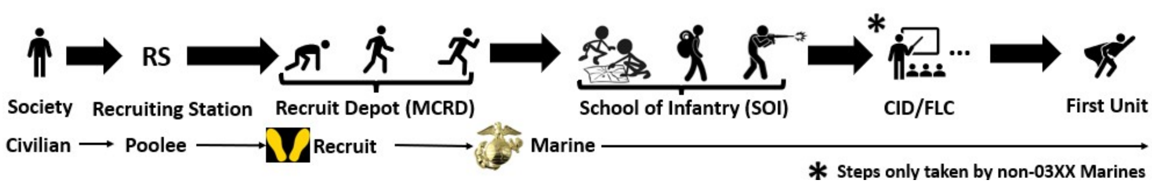

Figure 2.1. Overview of the "street-to-fleet" (STF) process a civilian takes to become a Fleet-ready Marine.

A brief characterization of the process is as follows:

1. A civilian makes contact with a Marine recruiter at a recruiting station, or perhaps more frequently the recruiter seeks them out at a high school, mall, sporting event, or other location where large numbers of eligible 17- to 28- year-old candidates tend to congregate.
2. If the civilian passes the initial questions of the recruiter they are then sent to MEPS where they are subject to a number of required aptitude tests, medical screenings, as well as criminal and other background checks. If they pass these, and once other required information is collected, that civilian is offered and signs an enlistment

contract (PEF or "open contract") with the Marine Corps. After this, approximately 8.8% of individuals proceed more or less directly to MCRD Parris Island or MCRD San Diego, depending on whether they live in the eastern or western United States respectively, and the other approximately 91.2% of Marine contracts are entered into the Delayed Entry Program, also known as the "pool program," where they are referred to as "poolee" until they ship to their MCRD (Marrone 2020). This delay in the pool program is often used by the recruiters as an opportunity to further prepare the poolees for the rigors they will face upon arrival at their respective MCRD. Of note, the poolee is not paid regular wages by the Marine Corps until the day they arrive at the recruit depot.

3. Upon arrival at their MCRD for recruit training, also known as "boot camp," the former poolee is now officially designated a "recruit" and will undergo 13 weeks of excruciating mental, physical, and emotional challenges to earn the title "Marine," assuming they are not part of the 12% to 16% who historically attrite (Harkins and Cox 2020). During their time at "boot camp" they will complete a number of physical tests, the results of which may later disqualify them for assignment to an MOS within their previously contracted PEF. For example, if a recruit cannot complete a certain number of pull-ups they may be disqualified from infantry-related occupational fields, or if they cannot achieve a certain combat water survival score in the pool they may be nonassignable to an MOS associated with operating Amphibious Combat Vehicles.
4. A couple of weeks prior to graduation, around training day 64, the recruit will be assigned an IMOS by the RDM monitor within MMIB, and will also be assigned to the course offering associated with the first course which they must attend on the path to complete their training to officially earn their PMOS. It is important to recognize, though, that some recruits are assigned an IMOS by the model which will then be further sub-classified into their final PMOS by designated sub-classification authorities at certain fleet learning centers (FLCs). Of note, even after completing all their training, when the Marine earns their PMOS the Marine may later attain one or more additional MOSs (AMOSs) after which it is common for their PMOS to change to represent their newly acquired MOS, and then for their previous PMOS to be listed thenceforth as an AMOS.
5. Upon graduation from recruit training the new Marine will proceed more or less directly to the SOI on the same coast as their MCRD for the next stage of their

training. TECOM is responsible for the sequencing of the start of SOI classes relative to the graduation of MCRD classes, and strives to do so with minimal delay.

6. After arriving at the SOI the recruits are placed in either Infantry Training Battalion (ITB) or MCT depending on the IMOS or basic MOS they were assigned. Infantry (03XX) occupational field MOSs are assigned to ITB and the rest are assigned to MCT. ITB currently lasts 59 days but is expected to expand to 94 days in the near future in order to accommodate the additional tasks expected of MOS 0311 Infantry Marines and other infantry-related MOSs in an Expeditionary Advanced Base (EAB). To this end, pilot programs of the new 94-day program were run at both SOI-East and SOI-West in FY 2021 (Athey 2021). The MCT training program currently lasts only 29 days for non-infantry combat service support (CSS) Marines before they move on to schools that will more specifically train them in their CSS role.
7. Upon graduation from SOI, the MOS 03XX Marines head directly to their first real (non-training) unit, accruing no MAT. All other CSS Marines must attend one or more follow-on MOS training courses before actually earning their PMOS and arriving at their first unit. Some of these training courses are administered at schools under the administrative control of TECOM, but a several are administered by other services within the Joint military community. As a result of this, a CSS Marine who graduates MCT may have to wait a significant number of months for the next iteration of their required MOS training course to commence, if they are issued a certain basic MOS at the “wrong” time of the year. This waiting time, called MAT time, is something the USMC recruit distribution model has significant ability to reduce, if desired, or to intentionally increase in order to allow a better GoF between a Marine and their assigned basic MOS.
8. After completion of the first course in their MOS training pipeline, CSS Marines may attend one or more additional courses in some of the lengthier MOS training pipelines before receiving their PMOS designation and arriving at their first fleet unit. Or, alternatively, they may receive their PMOS designation after only a single required course, depending on the IMOS they were assigned. As mentioned before, some model-assigned CSS IMOSs may be further refined into their eventual PMOSs by designated sub-classification authorities at certain FLCs. A good example of this is the Enlisted Aviation Maintenance Trainee Management Unit (EAMTMU) in Pensacola, which as of FY18 was responsible for sub-classifying enlisted trainees

into one of 68 possible PMOSs after having a chance to further assess them within the greater occupational field of aviation maintenance. This means that the best the USMC's chosen recruit distribution model can do is to send the right number of certain basic MOS types to the right courses to make it *possible* to fill the Marine Corps' stated annual requirements for each PMOS type, but that the school house instructors also have to be trusted to then sub-classify the correct number of each specific IMOS they were sent into the appropriate ratio of PMOSs, that will result in meeting the annual Classification Plan targets.

A more detailed timeline of the process for a specific recruit, showing the split between 03XX (infantry) and non-03XX (CSS) MOSs, is shown in Figure 2.2.

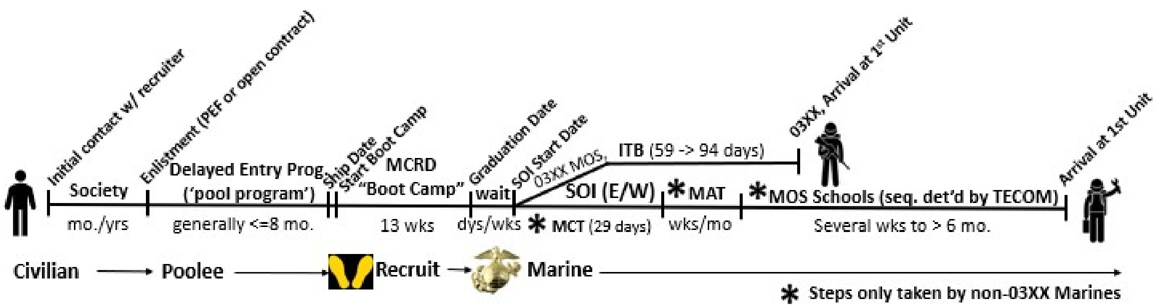

Figure 2.2. Detailed STF timeline showing infantry/non-infantry split.

Figure 2.2 shows where the split in required training occurs at SOI for those who are assigned an infantry occupational career code (OCC) MOS (03XX) (approximately 23% of the total, according to the FY19 Initial Class Plan) and those who are not, and illustrates how our model only really stands a chance to reduce MAT for the approximately 77.3% of non-infantry Marines that exist. Key milestones in the individuals' transformations are indicated extending from the top of the timeline at 45 degrees, with approximate times between these milestones indicated below the timeline.

Regarding these times, we note that while there are short waiting periods expected for the individual after they graduate from MCRD and before they start the SOI or MCT, and possibly between schools in their required sequence, these waiting times are under the control of Marine Corps TECOM and other Service training commands to affect based on the chosen frequency and sequencing of those courses. This means they are not something that our chosen recruit distribution model will be able to directly affect. On the other hand, the aforementioned MAT occurring immediately post MCT graduation (or really six weeks post MCT graduation to allow for the minimally-required personal leave) for CSS Marines is something that our chosen recruit distribution model will be able to have an effect on minimizing.

Additionally, at the front end of the timeline, it is worth noting that after a civilian signs an enlistment contract at a recruiting station and enters the Delayed Entry Program, they may have to wait in that poolee status for a long time (generally not to exceed 8 months), before their ship date to MCRD (MarineParents.com 2022). Despite this waiting time being lengthy, we are not overly concerned with it, as the U.S. Government (through the Marine Corps), does not actually begin financially employing these individuals until they actually ship to their recruit depot (as shown in Figure 2.3). Until this date poolees are expected to still be able to hold other means of employment.

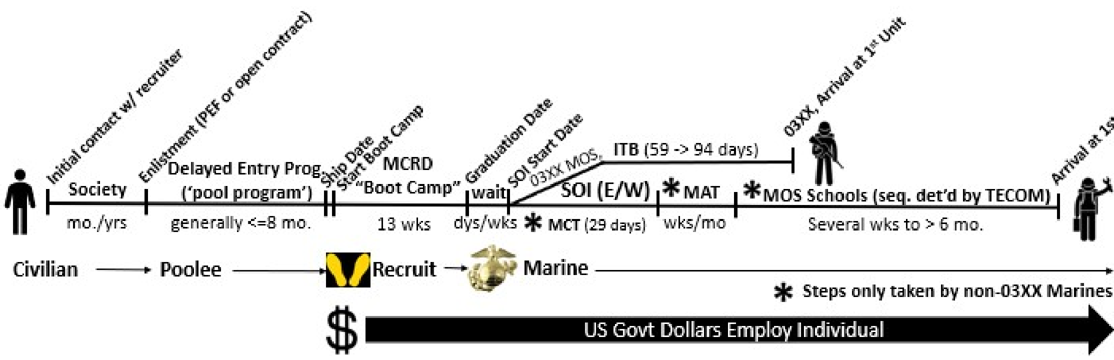

Figure 2.3. Shows when an individual in the STF process begins getting paid.

Also for further discussion in this thesis, it is important to note that when a civilian signs an enlistment contract at a recruiting station, they either sign a contract for a specific OCC area, a grouping of potential future MOSs that start with the same two digits and which is referred to as their PEF, or that civilian signs an "open contract," meaning they will later be assignable to any MOS for which they meet the minimum requirements. Naturally, the latter gives more flexibility later in what MOS to assign the recruit.

Figure 2.4 shows the major "touch points" of any chosen MOS and CID assignment model (in blue) prior to their arrival at their first unit.

Specifically, the current agreement between relevant Training Command and MMIB person-

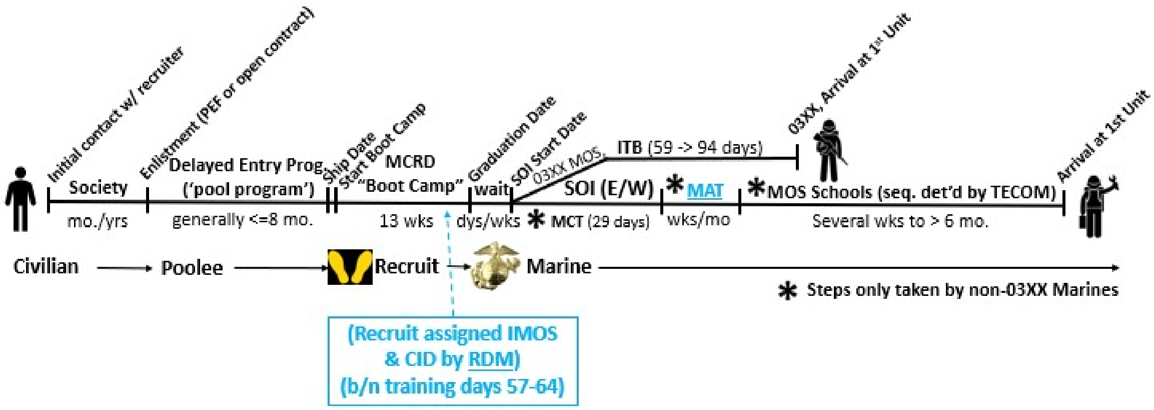

Figure 2.4. Shown in blue are the major "touch points" of any chosen recruit distribution model on recruits.

nel, is that Training Command is expected to have all necessary recruit physical fitness scores and other required information from the first portion of the recruit's recruit training entered and certified in Marine Corps Training Information Management System (MCTIMS) by the end of boot camp training day 56, so that MMIB can run the current RDM multiple times if necessary, and make any required manual MOS reclassifications to ensure all possible recruits have a basic MOS assigned no later than training day 64 (Gahagan 2021).

Regarding the importance of a recruit's GoF score with their assigned MOS, it is believed that if a recruit's initial occupational interests are better aligned with the MOS they are assigned, then they will have increased job satisfaction over their first term of enlistment. In turn we suspect increased job satisfaction must (at least slightly) increase their odds of retention at that important time in their career.

2.2 Current Solution: RDM

As noted previously, the current version of the RDM in use was completed approximately 10 years ago on 23 March 2012 (TCSI, MODELS 2020). As would be suspected of any model designed prior to the recent "pivot to the Pacific," it is not doing much to further the talent management initiatives of the current commandant of the Marine Corps. Moreover, its contracted support recently expired in July of 2021. In this section we give a wave-top overview of how the current model works and outline some of its key strengths and weaknesses.

2.2.1 Requirements and Overview of RDM

The latest contractor-supported iteration of the RDM was developed and released as one in a family of approximately 26 unconnected models, by the "MODELS" team within TCSI, monitored by Marine Corps Systems Command (MCSC) (Mauk 2022). While there must have been versions of the RDM before this one, this latest contractor-supported version was initially released on 14 Feb 2013 with 13 subsequent changes leading up to Revision 2.2 on 1 July 2020 (TCSI, MODELS 2020). In July of 2021, the contract support for the RDM and other models expired, and the responsibilities for its upkeep were transferred to Technology Services Organization (TSO), a Marine Corps organization under the umbrella of the DC Programs and Resources (P&R) consisting of approximately 11 Marines and about 400 to 500 civilians and contractors (Mauk 2022). It is a client/server system with client software that runs on the model user's Navy/Marine Corps Intranet (NMCI)-compatible computer at M&RA, which communicates with server software that runs on a separate server with backup procedures. The client computer communicates with the server over the M&RA local area network, and requires a Microsoft Windows 7 (or newer) operating systems (32 of 64-bit), Oracle client software (32-bit), and the actual RDM application software ('Rdm.exe' file), in addition to a 'Strat.ini' file in the same directory to properly operate (TCSI, MODELS 2020).

An overview of the inputs and outputs of the current RDM is shown in Figure 2.5.

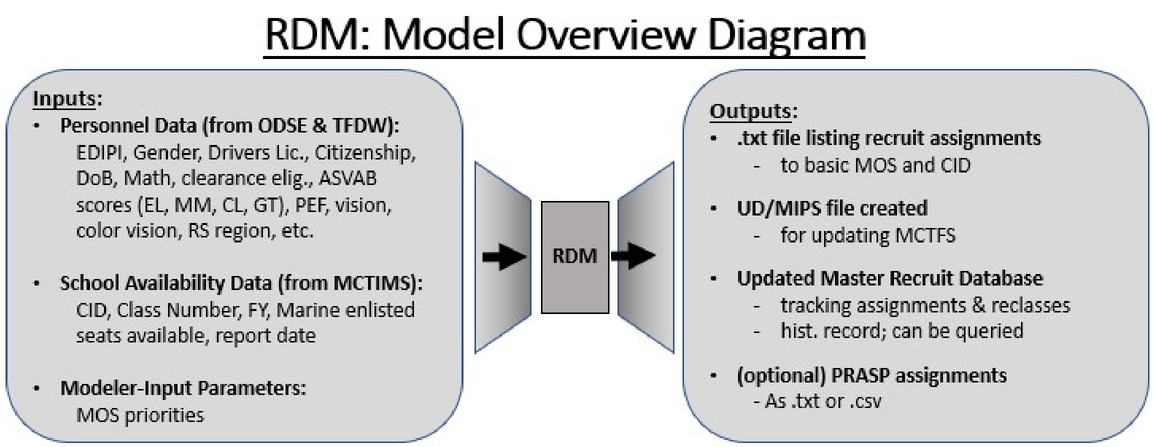

Figure 2.5. This is an overview of the current RDM, what it requires as inputs and what it produces as outputs.

In terms of inputs, the RDM requires personnel data, school and class seat data, and modeler input parameters and priorities. It draws personnel data from two primary sources: the Operational Data Store Enterprise (ODSE), and the Total Force Data Warehouse (TFDW). Its school and class seat data comes from MCTIMS. And its additional input parameters predominately consist of the modeler-assigned priorities given to each MOS, although it also allows the modeler to make a number of other changes to default inputs if desired.

The primary output of the RDM is the assignment of individual Marines to school seats, which is produced as a '.txt' file (TCSI, MODELS 2020). Optionally, when a run is published, RDM adds the solution data to a data structure known as the Master Recruit Database (which stores all historically published assignment data). Also, upon publishing, the RDM creates the files for data entry into Marine Corps Total Force System (MCTFS) via the Unit Diary/ Marine Integrated Personnel System (UD/MIPS) process, and creates various other files for ordering recruits to their initial training assignments (TCSI, MODELS 2020). As an additional option, the RDM can create a list of Permissive Recruiters Assistance Program (PRASP) assignments that can be used to intelligently select Marines who are expected to have sufficient waiting time, after completing SOI and prior to starting their first required CID, to be good candidates to head back to their home recruiting station for a brief stint of temporary additional duty (TAD) to help enlist future recruits.

2.2.2 Perceived Strengths of Current RDM Model in Use

The RDM has a number of known strengths that have made it an effective tool.

First, the RDM runs quickly and efficiently on a single run. Although Fortran is an older and more unforgiving programming language (for the programmer) than Python, Fortran code has faster run times than similar Python code, due to it being a pre-compiled language as opposed to an interpreted language. Although there are some methods available to squeeze faster run times out of Python, by default this makes Fortran actually slightly faster than Python in execution time (Bassett 2022). Of note, this expected difference in complete run times (including precomputation and solving time) for a problem of this size for a single recruit graduation run (if programmed similarly in both languages) would most likely be a matter of a few seconds or less. For doing the same for the whole FY it may be a matter of a few minutes.

The RDM gives the modeler significant flexibility to visually inspect the input tables of data that are pulled in from various sources prior to running the model and to make corrections to the data, if desired, before running the model.

The RDM produces output files that can be immediately used to update MCTFS and help effect orders generation for the Marines graduating from MCRD.

The RDM pulls "live" input data from the other required official authoritative systems (ODSE, TFDW, and MCTIMS) at the time it is run, and thereby does not require that information to be emailed or otherwise transferred from other entities, or to be input by hand by the model user at M&RA.

The RDM maintains a master history data file, the so-called Master Recruit Database, which tracks all recruit assignments that have been published since its inception. It also allows the model user to easily query this data file through a graphical user interface (GUI) in order to recall any details about previous assignments that have been made.

Finally, the RDM comes complete with a detailed user manual for the modeler to fall back on. Of note, the most recent update of this user manual occurred in 2020, and it is unclear when future updates, if any, will be made now that the ownership of support of the RDM has been transferred from the contracted MODELS team within TCSI to TSO under DC P&R.

2.2.3 Perceived Weaknesses of Current RDM Model

The RDM also has a number of known weaknesses.

Perhaps foremost, the RDM does not take GoF into account between Marines and the MOSs into which they are placed aside from checking that they meet the minimum aptitude requirements. That is, it does not take the interests of recruits into account in the slightest, beyond honoring previous contracts that they may have signed with the recruiter to place them within a specific group of MOSs if they signed a PEF.

The RDM does not consider trade-offs in MAT. It places even exceptionally qualified recruits (who well exceed the minimum Armed Services Vocational Aptitude Battery (ASVAB) requirements for most MOSs) in the first MOS with a school seat coming up that they meet the minimum ASVAB requirements for. It does so without consideration that they may perform better if placed in a different more challenging and rewarding MOS at a slightly later start date which would cause them to accrue some additional MAT in the short term, but would likely benefit the Marine Corps in the future by increasing their likelihood of career retention. In light of the current Commandant's recent guidance and intent to mature the force in order to succeed in future Expeditionary Advanced Base Operations (EABO) that he laid out in *Talent Management 2030*, it is likely it will be necessary to accrue some "good MAT" shortly after SOI graduations in order to increase the career retention probability of the same Marines down the road.

The RDM is written in a very unforgiving and now antiquated programming language, Fortran. This language is not taught at the Naval Postgraduate School nor routinely at other universities and does not come readily available within the newly mandated DoD Jupiter/advanced analytics (ADVANA) cloud computing environment. While the model running in Fortran may have been acceptable while the RDM was being maintained under contract by MODELS staff from TCSI, now that the contracted support of the RDM expired in July of 2021 and it is being maintained by programmers and Marines within TSO, it is less likely they will have the skill set necessary to modify the baseline Fortran code to maintain a relevant model that can evolve to meet the changing future needs of the Marines Corps.

The RDM routinely produces infeasible results that require manual intervention to fix. Nearly every graduation run of the RDM produces at least a few infeasible classifications requiring the model user at M&RA to manually reclassify recruits into different MOSs. This typically occurs because the model assigns recruits to an MOS for which they do not meet the minimum physical fitness requirements based on their most recent test scores at MCRD, such as when they do not meet the required number of pull-ups to be classified into an infantry MOS. Infeasible assignments also frequently happen when the model assigns a recruit an initial school seat at a Joint service school that appears to have an available seat in MCTIMS at the time the model is run, but which was actually already filled in the sister service's training system and failed to show in MCTIMS due to the latency between the two systems and the timing and frequency at which they are updated. Unfortunately, both of these errors frequently result in graduating recruits being assigned to MOSs and initial schools for which they are unqualified or there are no seats available. When this occurs, neither the school house nor the recruit may recognize there is an issue until the recruit travels to the school and is turned away at the door for required reclassification or additional MAT time. Obviously, this wastes both the time of the recruits and Marine Corps dollars, and gives the new Marines the sense of mishandled by the Marine Corps at a very early and significant stage in their young careers. It is only through the tireless efforts of the model users at M&RA currently that many of these infeasible assignments created by the model are being caught before they are published. Still, this situation is far from ideal, and in FY19 alone the RDM's infeasible results led to 1,718 Marines needing to be manually reclassified through official message traffic (McGhee 2022a).

The RDM requires the use of excessive manpower hours to classify "open contract" recruits and leads to unnecessary classification errors. As opposed to simply classifying open contract recruits alongside all the others in a given model run, the RDM does not classify them at all and thus forces the model user to manually classify them. This means the model user has to individually attempt to verify each recruit's eligibility based on ASVAB scores, physical fitness scores, family citizenship background, clearance level, driver's license status, left or right eye dominance, and a slew of other factors. The user must do this for each open contract recruit for each target MOS with upcoming course offerings, and then look within MCTIMS or a sister-service training system to determine if there are seats available for the highest-priority MOS course, so the modeler can then manually classify the recruit into that MOS course in their temporary tracker. Once the modeler fills out the temporary assignment tracker manually in this way for all the open contract recruits, then they still have to "publish" the final results of the tracker to officially lock in all of the temporarily assigned manual reclassifications they conducted. This process can be so time consuming that by the time they go to publish their manual reclassification results, course seats that appeared available when they conducted their initial review may actually no longer be available within MCTIMS or the sister-service training system. As a result, they may end up publishing recruit/MOS course assignments that send recruits to schools that are full, even if in theory they did everything perfectly, simply due to the time required for conducting numerous manual reclassifications.

2.2.4 The 2021 "Modernized Recruit Distribution Model"

Based on the perceived weaknesses of the RDM listed above, in 2021 Marine Corps Captain Ryan Martinez set out to build a better recruit distribution model from the ground up (Martinez 2021). Captain Martinez felt strongly that the Marine Corps required a tool that would do a better job of incorporating GoF, which would conduct reclassifications of infeasible recruit assignments automatically, and which would be more flexible in its application under the model user once built. Specifically, he set out to build a model which would allow the user to pull three metaphorical "levers" to adjust the relative importance of what he perceived to be the three most important pillars that any model solution would need to balance. He defined these pillars as: 1) minimizing the expected MAT time associated with the recruit MOS and CID assignments; 2) penalizing failing to meet the immediate billet "needs of the Marine Corps" in the assignments; and 3) maximizing the GoF between recruits and their assigned MOS.

For the GoF metric, Martinez (2021) decided to use ASVAB scores of 110% of the minimum aptitude requirements for each MOS as the ideal GoF level for each MOS. He decided to use this somewhat arbitrary metric as a placeholder to peg the ideal GoF between a Marine and an MOS until a better solution could be implemented, and justified it based on the work of psychologists Yerkes and Dodson (Jankowski 2022) which implies that if Marines we not challenged enough by the MOS they were assigned or if they were challenged too much, each would have a detrimental effect on their eventual performance in that MOS. Martinez (2021) knew that work was being done concurrently by operations analysts at M&RA on a Marine Corps Occupational Specialty Matching (MCOSM) tool that was being designed to help gauge a potential recruit's true interest alignment with each of the many available MOSs in addition to measuring their aptitudes for the MOSs via their ASVAB scores. But absent any actual interest or aptitude scores of recruits from this conceived tool being available yet, he proceeded with only the 110% of minimum required ASVAB category scores as representing the ideal recruit-to-MOS matching for purposes of GoF.

The resulting M-RDM has more required inputs and produces fewer outputs than the original RDM. Figure 2.6 provides a high-level overview of M-RDM.

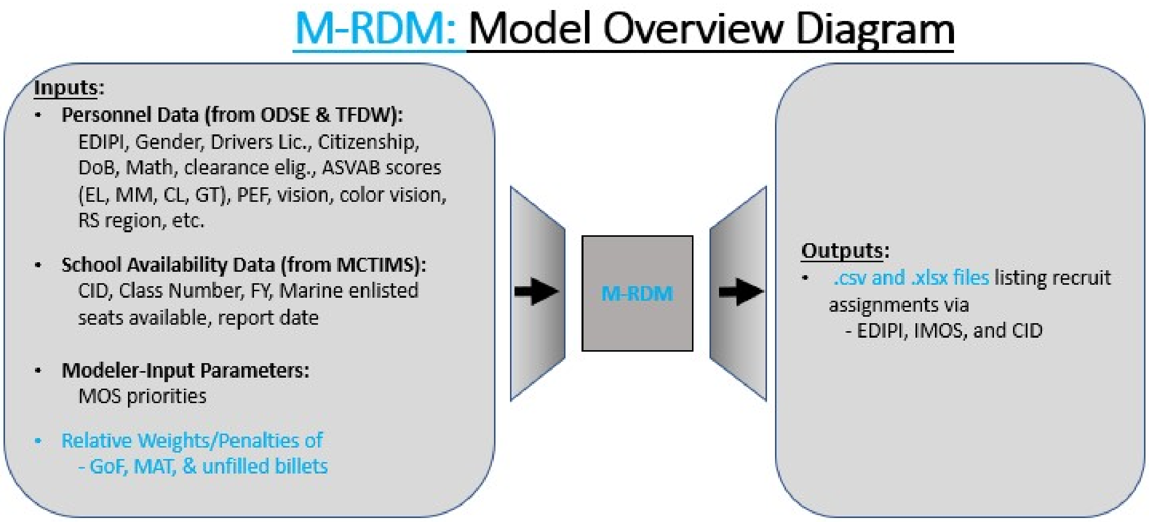

Figure 2.6. An overview of the M-RDM, what it requires as inputs and what it produces as outputs. Changes from the RDM are shown in blue text. Note that three outputs from the RDM are non-existent in the M-RDM.

M-RDM: Key Contributions

The M-RDM represents a significant leap forward for Marine Corps talent management initiatives through its high potential to increase the proportion of first-term and subsequent-term Marines who reenlist in order to help "mature the force" in keeping with the Commandant's *Talent Management 2030* initiatives. Through its ability to incorporate GoF scores from the MCOSM model (if further developed) it will help ensure Marines are placed in MOSs that align with not just their aptitudes, but also their *interests*, for the first time. In so doing, it is expected to increase first-term and subsequent-term retention rates which will help enable the Marine Corps to reap the advantages of maturing the force, particularly in the context of EABO where the Commandant states the need to do so.

The M-RDM is written in a more modern, flexible, and programmer-friendly programming language, Python, than the current RDM, which is written in Fortran. This will allow the Marine Corps to more readily migrate it onto the newly required and data-forward Jupiter/ADVANA network in the future, and possibly without having to pay a contractor to do so, as dozens of new NPS graduates are returning to the Fleet with Python knowledge with every summer graduating class.

The M-RDM greatly simplifies the required process for the model user at M&RA in the output verification step by not requiring them to manually reclassify recruits that are found to fall short of minimum physical fitness requirements. The M-RDM takes care of all necessary reclassifications based on physical fitness shortfalls observed at the MCRD, assuming the modeler inputs the physical fitness scores of the recruits before running the model. Unfortunately it still does not have a way to catch assignments made to sister-service schools' class seats that appear available in MCTIMS at the time the model is run but which were really filled at the last minute in the sister-service training system, but which had not yet been updated in MCTIMS due to the inherent lag time in MCTIMS being updated with data from the sister-service system.

M-RDM: Opportunities for Additional Improvement

The M-RDM doesn't have "live" data links to the necessary databases for pulling all the inputs (e.g., ODSE, TFDW, MCTIMS). As a result, it currently lacks the ability for a modeler to use it and keep up with the op-tempo of the recruit depots (i.e., the speed at which graduations occur). When Captain Martinez demonstrated the new model on two recruit class graduations, he did so after painstakingly data-mining the necessary historical information from the M&RA model user and the other necessary systems and after making numerous assumptions to proceed with his analysis along the way.

The M-RDM only assigns recruits one model-run (recruit MCRD recruit graduation class) at a time, and therefore is not able to withhold a Marine who may be unusually qualified from being placed in a CID in a current model run and follow-through to ensure they get placed in a more appropriate CID in a later model run. While the M-RDM incorporates the notion of "good MAT," it does so by recognizing that it may be okay to assign each recruit additional MAT on a particular model run, if they help fill a necessary target and are a good fit for the chosen MOS. Due largely to this, it remains unclear whether the model would truly perform better for the Marine Corps over the course of a whole fiscal year, than the current RDM does.

The M-RDM does not have a way of automatically rolling a Marine who does not get assigned a CID in the current model run (a "non-designated Marine") into the next model run. This is important, because these Marine obviously do not disappear, and if there is a problem with them in one model run, who is to say there will not be one in the next model run?

The M-RDM currently lacks a mechanism to create consolidated historical records of all model inputs, parameters, and outputs from each model run, where the current RDM updates its built-in Master Recruit Database.

The M-RDM is currently less user-friendly than the RDM for the billet-designated USMC model users. There are two such users within MMIB. The primary "RDM Monitor" billet is coded for a gunnery sergeant and the alternate "Reclassification Monitor" is coded for a staff sergeant. Each of these billets require zero expected prior training in computer programming, whereas the M-RDM currently requires an understanding of how to at least execute from a command line terminal a script written in Python. By comparison the RDM just requires them to be able to use an executable spreadsheet-based application that comes with an intuitive GUI and lengthy user manual to fall back on.

2.2.5 Related Models and Decision Support Tools – Current

M&RA deploys several plans and models in the manpower process upstream of the RDM and TECOM plays a key role (downstream from there) in determining the start dates of all MCRD classes, SOI classes, and follow-on Marine Corps MOS schools, that a recruit must attend. Where these various models and decisions impact a Marine recruit on their STF timeline are shown in Figure 2.7. In this section we will discuss the most significant upstream M&RA plans and models briefly.

Within M&RA's Manpower Plans Programs and Budget Branch (MPP), Enlisted Plans Section (MPP-20) determines the monthly PEF allocations that MCRC will recruit to in the upcoming fiscal year (United States Marine Corps 2018). The program plan is created by back-planning from a future First Term Alignment Plan (FTAP) requirement and taking into account expected MOS school, MCT, and MCRD attrition that will precede that requirement to determine the appropriate amount of each PEF to be recruited in the upcoming FY (United States Marine Corps 2018).

The annual classification plan (ACP), also created by MPP-20, determines what the appropriate number of entry-level Marines to produce in each MOS should be within the upcoming fiscal year accession cohort or recruits. An accession cohort is defined as all

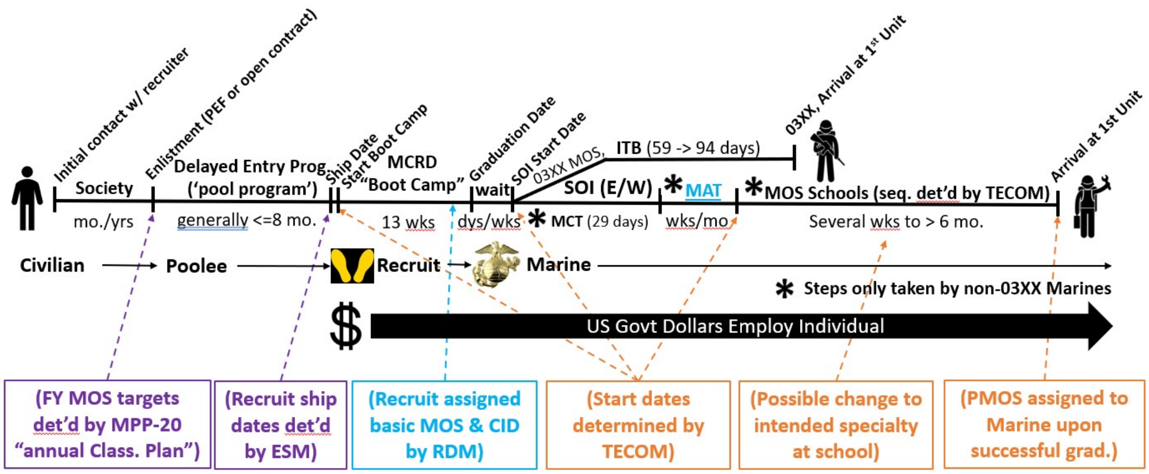

Figure 2.7. Interplay of chosen recruit distribution model with upstream M&RA models (in purple) and downstream TECOM models or actions (in orange).

Marines who ship to MCRD within a given fiscal year. It does so by taking into account current force design initiatives, desired end of FY strength by MOS and rank, the current manpower inventory by MOS and rank, and the forecast MOS attrition over the coming year by MOS and rank (United States Marine Corps 2018). The result provides the overall entry-level accession target numbers for each MOS for the coming FY. This is then required as an input for the Enhanced Shipping Model (ESM).

The ESM, created by Major Alex Ryan and Major Robert Jankowski at M&RA, takes the overall ACP quantities by MOS of junior Marines that need to be produced over the whole FY and breaks them down into recruit graduation class sized chunks of certain types of contracted poolees that should be shipped to the MCRDs at specific times throughout the year. It does this in order to best align them with the MOS schools that they will be required to attend (if they have signed PEF contract) or that they will likely be required to attend, with the goal of shipping the right type of poolees at the right time to significantly reduce their MAT later. Therefore, the two main inputs of the ESM are the ACP and the listings of all scheduled MCRD and MOS school start dates for the FY in question. It is important to realize that if any of these inputs change throughout the FY the ESM should be re-run. As its outputs the ESM produces the quantities of specific types of contracted poolees that should be shipped to their assigned MCRD on specific dates and it also provides the target number of each IMOS type Marine that ideally should be created from these groups of poolees by the RDM shortly prior to their graduation from MCRD. That is, the MOS target outputs of the ESM form one of the critical inputs of the RDM in terms of determining how well a chosen solution of the RDM meets the “needs of the Marine Corps” in filling the target numbers of each type of basic MOS that were assigned by the ESM to that specific recruit class.

2.2.6 Envisioned Manpower Models and Decision Support Tools

M&RA has an elaborate network of interwoven models envisioned that impact the overall human resources development process (HRDP) in order to better achieve the Commandant’s intent as described in *Talent Management 2030*. Some of these models are currently live in the newly-mandated Jupiter/ADVANA cloud-based analytics environment, whereas others are in the process of being migrated into that environment, and some are only envisioned at this time as shown in Figure 2.8.

2.3 Contributions of This Thesis (in Context)

We look to improve on the existing M-RDM work in several ways.

We make corrections to some of the existing model code, particularly in the areas of determining recruit-MOS eligibility when it comes to swimming qualifications and Marine Combat fitness test scores, and in the area of determining overall recruit-to-MOS goodness of fit scores for MOSs with three or more ASVAB skill area requirements.

We recommend and implement new default objective function weights (expressed by λ values in the forthcoming formulation) based on the perceived value to the Marine Corps of each component therein.

We simplify some of the set terminology used in the model formulation, replacing the *ELIGIBLE* and *TAUGHT* sets of pairs with a single *ASSIGNABLE* set of recruit-MOS-course offerings triples in most places.

We provide theoretical extensions on how the existing single graduation run model may be formulated across a whole fiscal year in three new ways. Out first approach feeds the results

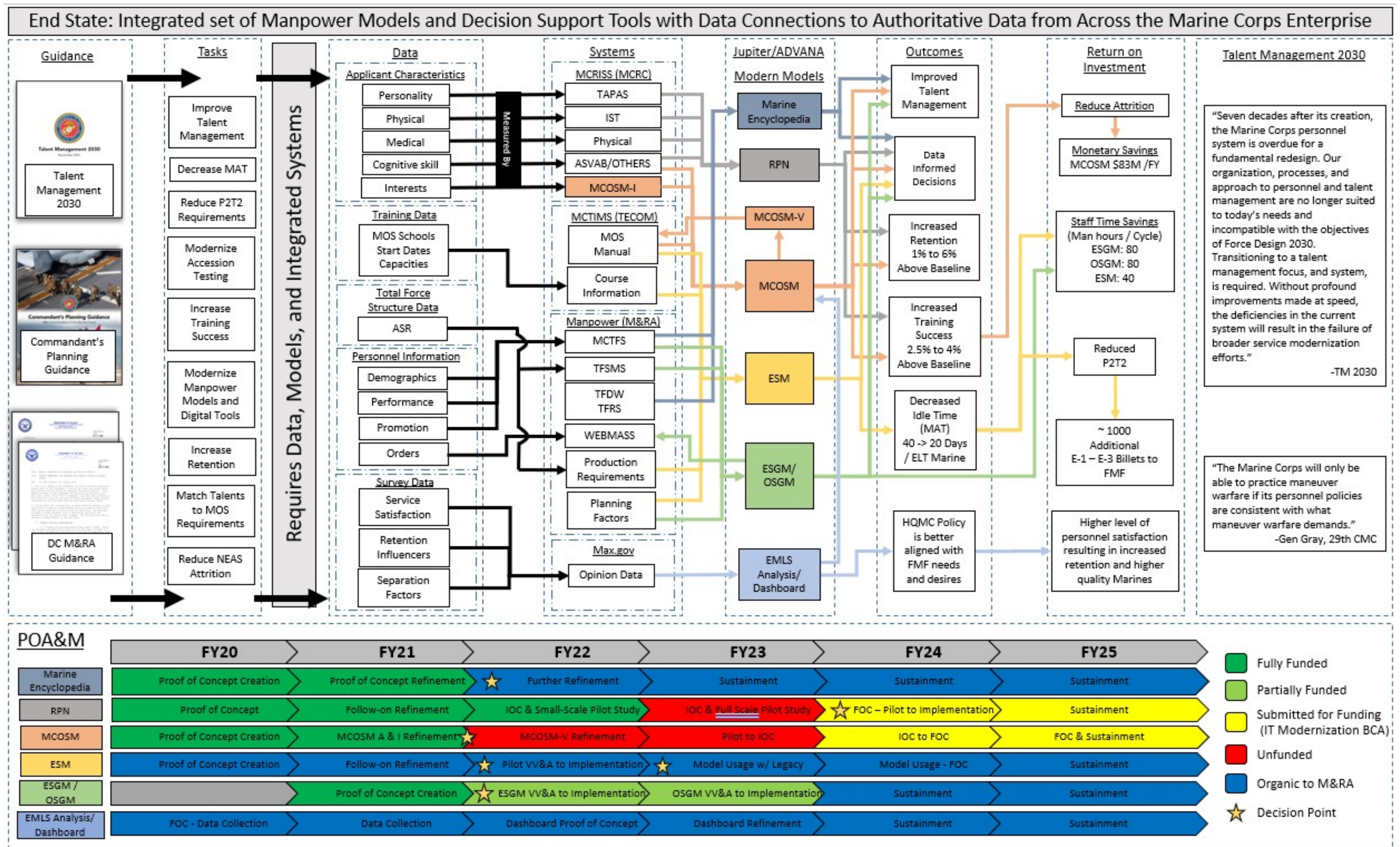

Figure 2.8. Version 3 of the Manpower Studies and Analysis (MPA) Project Placemat as of 31 January 2022. Source: Jankowski (2022a).

of one graduation run into the next, incorporating the idea of "persistence" between model runs. It sets target MOS classification numbers for each graduation class based on outputs from the ESM and from previous M-RDM results. This approach solves a separate integer linear program for each of the required MCRD graduation classes throughout the year.

Our second approach penalizes MOS classification shortfalls and overages for each MCRD graduation class based on all MOS classification targets being set for each graduation class at the beginning of the year as informed by ESM outputs. This fiscal year solve type solves a single larger integer linear program that penalizes shortfalls and overages to each graduation class's MOS classification targets throughout the year.

The third proposed approach penalizes only the end-of-year MOS classification shortfalls and overages, allowing more flexibility for variation in assigned MOSs from one model run to the next throughout the FY.

We create all necessary historical input files and solve the model for FY19 using the first fiscal year solve type outlined above and provide end-of-year side-by-side analysis of the historical RDM assignments alongside the new M-RDM assignments that were made. We hope this will allow M&RA decision-makers to see which model performs better over the course of a whole fiscal year in order to more safely choose which model they would prefer to use moving forward.

Finally, we set the ground for movement to Jupiter/ADVANA environment, by ensuring all Python code will work therein.

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CHAPTER 3: Model Technical Contributions

In this chapter we revisit the M-RDM formulation, discussing generally how it works, its strengths, and its inherent biases. To adjust for these biases, we provide recommended default objective function coefficient weights to be used in all M-RDM runs before potentially making any deliberate coefficient adjustments thereafter. In terms of other adjustments to the baseline M-RDM, we describe two coding corrections made to the M-RDM to address GoF calculation errors that were being made for MOSs with three or more required ASVAB skill areas and to address the erroneous functionality of the advanced swimming qualification feasibility check on recruits for specific MOSs. Next, we introduce new sets and indices to describe the problem of solving for the many graduation runs required over a whole FY, before then describing two newly conceived model formulations M-RDM-22a and M-RDM-22b and their associated benefits. Last, we detail the specific comparative metrics that will be used in Chapter 4 to clearly discuss the outcomes of the different models at the end of the 36 different MCRD graduation class model runs that occurred in FY19.

3.1 M-RDM Model Formulation

The mathematical formulation for the M-RDM is an integer linear program with indices, sets, parameters, and decision variables, described in Martinez (2021) as follows.

Indices and Sets

$r \in R$	Recruit
$m \in M$	MOSs
$c \in C$	Course Identification Code (CID) Offering
$(r, m) \in ELIGIBLE \subseteq R \times M$	Recruit r is eligible for MOS m
$(m, c) \in TAUGHT \subseteq M \times C$	MOS m is taught at CID offering c

Input Parameters

$MAT_{r,c}$	MAT time for assigning recruit r to CID offering c

$gf_{r,m}$	Goodness of fit for assigning recruit r to MOS m
$avail_c$	Available school seats for CID offering c
$target_m$	Target number of recruits assigned to MOS m
$\lambda_m^{shortfall}$	Penalty per recruit under target for MOS m
$\lambda_m^{overage}$	Penalty per recruit over target for MOS m
λ_{MAT}	Penalty for incurred MAT time
$\lambda_{goodfit}$	Penalty for goodness-of-fit score

Decision Variables

$X_{r,m,c}$	Assign recruit r to MOS m taught at CID offering c [binary]
$SHORTFALL_m$	Number of recruits below target for MOS m
$OVERAGE_m$	Number of recruits above target for MOS m

M-RDM Formulation

$$\min_{\substack{X\\SHORTFALL\\OVERAGE}} \sum_{\substack{(r,m)\in ELIGIBLE\\c:(m,c)\in TAUGHT}} X_{r,m,c}(\lambda_{MAT}\ MAT_{r,c} - \lambda_{goodfit}\ gf_{r,m}) + \sum_m (\lambda_m^{shortfall}\ SHORTFALL_m + \lambda_m^{OVERAGE}\ OVERAGE_m) \quad (3.1)$$

$$\text{s.t.} \quad \sum_{\substack{(m,c)\in TAUGHT:\\(r,m)\in ELIGIBLE}} X_{r,m,c} = 1 \qquad \forall r \in R \quad (3.2)$$

$$\sum_{\substack{(r,m)\in ELIGIBLE:\\(m,c)\in TAUGHT}} X_{r,m,c} \leq avail_c \qquad \forall c \in C \quad (3.3)$$

$$\sum_{\substack{r:(r,m)\in ELIGIBLE\\c:(m,c)\in TAUGHT}} X_{r,m,c} = target_m - SHORTFALL_m + OVERAGE_m \qquad \forall m \in M \quad (3.4)$$

$$X_{r,m,c} \in \{0,1\} \qquad \forall r \in R, m \in M, c \in C \quad (3.5)$$

$$SHORTFALL_m, OVERAGE_m \geq 0 \qquad \forall m \in M \quad (3.6)$$

Discussion

This model considers the assignment of a single set of recruits graduating from the MCRD.

The objective function (3.1) balances three competing terms: the sum of all the recruits' expected MAT time for their assigned courses (less is better); the sum of the GoF scores with the recruits and their assigned MOSs (more is better); and the number of recruits both above and below the target number for each MOS (less is better). The relative weights for these terms are controlled by the penalty terms λ_{MAT}, $\lambda_{goodfit}$, $\lambda_m^{shortfall}$, and $\lambda_m^{overage}$, respectively.

Equation (3.2) mandates that, within the set of recruits and their eligible MOSs and corresponding initial courses considered in the MCRD graduation run, each recruit will be assigned to exactly one specific MOS and initial course offering.

Equation (3.3) ensures that, within the set of eligible recruit-to-MOS assignments and the set of course offerings that are taught for those MOSs, the total number of recruits that are assigned to any specific course offering cannot exceed the available number of seats for the Marine Corps at that course offering.

Equation (3.4) calculates the shortfall or overage for each MOS relative to the ESM target.

Stipulation (3.5) ensures that each recruit will either be assigned once, or not assigned at all, to each specific MOS and course offering pair.

Stipulation (3.6) is a non-negativity constraint on the shortfall and overage variables associated with each MOS.

An important aspect of this formulation is the precomputation of sets $ELIGIBLE$ and $TAUGHT$ within the M-RDM code prior to running the main integer linear program formulated above. Recruit $r \in R$ is determined to be eligible for MOS $m \in M$ within a given model run, if r is included in the group of recruits graduating in the specific model run and they meet MOS-specific requirements for ASVAB skill scores, height, vision, mathematical skills, swimming qualifications, citizenship, and security clearance (see Martinez 2021, for details). Separately, data provided by TECOM indicates whether MOS $m \in M$ is taught at CID offering $c \in C$. In addition, this formulation requires the precomputation of goodness-of-fit $gf_{r,m}$ for each recruit $r \in R$ and MOS $m \in M$ (again, see Martinez 2021, for details).

3.1.1 Strengths of the M-RDM

The M-RDM has a number of potential strengths over the legacy RDM.

Flexibility of the M-RDM to Strategic Context. The objective function (3.1) is flexible in the sense that each of the aforementioned metrics and variables it strives to maximize or minimize (i.e., $MAT_{r,c}$, $gf_{r,m}$, $SHORTFALL_m$, and $OVERAGE_m$) are prefixed by an objective function coefficient (represented by the λ terms) which determine the relative importance of those metrics to the overall recruit-to-MOS-and-initial-course assignments the model produces. In other words, by adjusting these λ parameters appropriately, we can bias the model toward solutions that place increased importance on one or more of these metrics over the others.

As envisioned by Captain Martinez, this could be very useful for the model users depending on the greater strategic environment in which the model is to be run. For example, if there was an immediate need to fill a great many new MOSs and/or existing MOSs with greater numbers of Marines, then it would presumably make sense to increase the $\lambda_m^{SHORTFALL}$ objective coefficients (penalty) for each MOS far above the other coefficients in the model. It would also make sense in this scenario to weight the objective function coefficient for MAT to give that metric the second highest priority (penalty for growing it), to ensure the model would not only produce the necessary MOSs, but would do so in a manner that pushes initial recruits to their assigned initial MOS courses with as little delay as possible. Alternatively, if the Marines are looking to save money in the area of manpower management (here primarily considering recruiting and initial training), it would make sense to more heavily weight the lambda objective function coefficient for the "goodness of fit" metric over others, in order to ensure that the recruit-to-MOS assignments made by the model would favor that metric. We would expect this to lead better job performance and job satisfaction of the Marines in their assigned MOSs over their first term, therein leading to greater expected retention rates and a lesser cost required of MCRC and TECOM in the coming years to recruit and provide entry-level training for necessary replacements. This increased weighting of $\lambda_{goodfit}$ would also seem to be the primary way to use the model to work toward the Commandant's desire to "mature the force" in order for it to perform better in the context of EABO.

A Modern Computational Framework. Despite the slight run-time efficiency benefits of Fortran over Python, highlighted previously in Section 2.2.2, there are numerous advantages of using a modern programming language such as Python for the problem of recruit assignments.

First, although *run-time efficiency* can be an important consideration for large-scale big-data problems, the size of this problem is not really large enough when compared to the computing power of even most modern personal computers to necessitate run-time efficiency being a focus. Our primary customer is the staff sergeant model user within MMIB. As long as they can execute the model within a matter of a handful of minutes, it will be sufficient for them to run it multiple times throughout the work day if needed or desired to compare possible alternative solutions based on adjusted input parameters. This slightly longer run time should especially be acceptable to the user when you consider that the M-RDM will make all necessary MOS reclassifications for them during the model run, which the RDM does not.

A better consideration for the ideal model programming language perhaps should be *coding and updating efficiency*, due to the numerous updates that are necessary and will continue to be necessary to keep the model running smoothly for the Marine Corps in future years. Every year, to meet the constantly changing needs of the Marine Corps, MPP publishes a new

ACP and new recruiting program codes (detailing the PEFs offered), Training Command publishes a new course schedule, and M&RA and TECOM may even come together to release a new MOS Manual and create entirely new MOSs with associated minimum requirements. And of course, not all of these documents can be depended upon to come out at the same time of the year, so the parameters of the problem being solved may change numerous times throughout any given year. Thankfully, to work through all of these constant changes, particularly in light of the original contract support having recently expired for the RDM in July of 2021, there are designated billets for Operations Analysts (graduates of the NPS 8850 curriculum) within M&RA and TECOM to help update all the necessary scripts accordingly. While at NPS, those 8850 students are currently taught how to program in Python and are expected to acquire the use of R as well, but they are not taught or expected to learn Fortran. Python and R are similar enough languages that it is reasonable for the students to learn both over their two-year curriculum. Each language is interpreted, object-oriented, relatively user-friendly, and free to download online with thousands of additional freely available packages and associated help documents available as well. The latest version of Fortran, on the other hand, is precompiled (not interpreted at run time), is not freely available, not object-oriented, and does not come with as large a community of online users to create additional packages or to provide help for programming problems encountered. Ultimately, even the most run-time efficient model is of little or no value if the model itself is not kept up to date.

Lastly on this subject, Python is better postured than Fortran to make the forthcoming switch to the DoD's newly mandated ADVANA cloud-based software, computing, and analytics environment. The Navy's Jupiter enclave within ADVANA currently has interactive development environments (IDEs) that can run Python, R, and some versions of C, but does not include software that can run Fortran code at this time. Whether or not it ever will is currently unclear, but we have to suspect that ADVANA will continue to work to field cloud-based software and computing environments that meet the demands of most of the young and mid-grade DoD programmers that are entering the ranks. Right now the majority of that demand within the DoD analytics community is for software and development environments that can run Python and R kernels, as evidenced by the Operations Research curriculum at NPS.

3.1.2 Opportunities to Improve the M-RDM

The work of Martinez (2021) sets the stage for several additional improvements.

Inherent Bias in Default M-RDM Coefficients. In the case where objective function coefficients (λ terms) are all set to one, and knowing a bit about the data involved in this problem, we suspect this model formulation to have a default bias toward minimizing expected MAT time over the other considered metrics and variables. This is for the simple reason that the default units of MAT time in this problem are measured in expected days per recruit and tend to be on the order of weeks to months with an average of about 31 days per recruit. Compare this to the default units of GoF which are in a ratio of recruit ASVAB scores to minimum MOS requirements and which generally vary from about 0.91 (for a minimally qualified recruit in each ASVAB area compared to the 110% standard) to no more than 1.00 per recruit (for the perfectly 110% qualified recruit in each required ASVAB area) Martinez (2021). So we see here, that in general, just based on the magnitude of the differing units used in the objective function, we may be inherently weighting the importance of expected MAT per recruit as much as around 30 times more than we are weighting their GoF with their assigned MOS, if we do nothing to correct this by adjusting their λ coefficients.

As to the other two variables, $SHORTFALL_m$ and $OVERAGE_m$, each is measured in the number of recruits assigned by the model below or above the ESM target respectively for each of the 146 different assignable MOSs in FY19 and is summed across all MOSs within the eligible set in the model run. Compare this number of 146 MOSs to the approximately 300 recruits that graduate from each single coast MCRD graduation (of which there were 17 in FY19) and the approximately 600 that graduate from each combined coast MCRD graduation (of which there were 32 in FY19) and you start to get a sense of the what the relative default prioritization of these variables is in the objective function compared to the metrics associate with each recruit assigned. As an example, if each MOS considered in the model run were short one assigned recruit, then it would result in an increasing of the objective function value by 146 units or less (less if the eligible set of recruits and MOSs for the model run included fewer than the total 146 MOSs). By comparison, if each recruit accrued an additional one day of expected MAT time, across the approximately 600 recruits in a typical bi-coastal model run, then this single additional day per recruit would result in the increasing of the objective function value by approximately 600 units, simply due to the differing sizes of the considered sets. This means that by default the model essential prioritizes the minimization of one day of expected MAT per Marine four times as highly as it prioritizes avoiding being short an additional Marine in each MOS.

The default bias toward minimizing MAT is likely not ideal for this model as other "upstream" models such as the ESM have already sought to minimize MAT and therefore there may really be little remaining room for this model to continue to improve in this area. To expound on this, a group of poolees with certain contracted PEFs and personnel attributes would have already been shipped to the MCRD together as a class based on the upcoming TECOM course schedule for initial entry-level MOS training with the primary intent of minimizing expected MAT time. Therefore the recruit class that is graduating for each model run likely will not be able to improve a lot further in the area of minimizing expected MAT, even with the highest of objective function coefficient weights applied to that metric. We must ask next, "If not MAT, which of the objective function metrics or variables should the M-RDM prioritize by default?" See Subsection 3.3.1 for more on this.

Solving for an Entire Accession Cohort. The M-RDM formulation in Martinez (2021) solves for a single graduation only. Yet, the primary mission of M&RA and MMIB is to meet manpower needs over an entire FY. We address this need explicitly in Section 3.2.

3.2 An Updated M-RDM

We extend the formulation in Section 3.1 in order to solve for MOS assignments for all graduations across a FY recruit accession cohort. We begin with the following additionally required notation.

Additional Indices and Sets

$g \in G = \{1, 2, ..., 36\}$	Chronologically numbered graduation classes during the FY
$r \in R_g$	Recruit r graduates in class g, where $\cup_{g \in G} R_g = R$ and $R_g \cap R_{g'} = \emptyset \;\; \forall g \neq g'$
$(r, m, c) \in ASSIGNABLE$	Recruit r is assignable to MOS m and course offering c

Additional Data

$target_{m,g}$ — The ESM-assigned target for MOS m in graduation run g from within the FY recruit accession cohort

Additional Decision Variables

$X_{r,m,c}$ — Binary decision variable reflecting if recruit $r \in R_g$ is assigned to MOS m and course offering c in graduation run g

$SHORT_{m,g}$ — Number of recruits below target for MOS m in graduation run g

$OVER_{m,g}$ — Number of recruits above target for MOS m in graduation run g

M-RDM-22 Formulation

For a single fixed $g \in G$, the following "M-RDM 2022" (M-RDM-22) formulation is equivalent to the original M-RDM.

$$\min_{\substack{X \\ SHORT \\ OVER}} \sum_{\substack{(r,m,c) \in ASSIGNABLE: \\ r \in R_g}} X_{r,m,c}(\lambda_{MAT}\, MAT_{r,c} - \lambda_{goodfit}\, gf_{r,m}) + \sum_{m} (\lambda_m^{shortfall}\, SHORT_{m,g} + \lambda_m^{overage}\, OVER_{m,g}) \tag{3.7}$$

$$\text{s.t.} \sum_{(r,m,c) \in ASSIGNABLE} X_{r,m,c} = 1 \qquad \forall r \in R \tag{3.8}$$

$$\sum_{(r,m,c) \in ASSIGNABLE} X_{r,m,c} \leq avail_c \qquad \forall c \in C \tag{3.9}$$

$$\sum_{\substack{r \in R_g: \\ (r,m,c) \in ASSIGNABLE}} X_{r,m,c} = \Big[target_{m,g} - SHORT_{m,g} + OVER_{m,g} \Big] \qquad \forall (m,g) \in M \times G \tag{3.10}$$

$$X_{r,m,c} \in \{0,1\} \qquad \forall (r,m,c) \in ASSIGNABLE \tag{3.11}$$

$$SHORT_{m,g}, OVER_{m,g} \geq 0 \qquad \forall (m,g) \in M \times G \tag{3.12}$$

Discussion

In this formulation, the target values for the single graduation class, $target_{m,g}$, are equivalent to $target_m$ in the original formulation in Section 3.1. Similarly, the variables $SHORT_{m,g}$ and $OVER_{m,g}$ respectively play the roles of $SHORTFALL_m$ and $OVERAGE_m$ in the original formulation.

In this formulation, the single set $(r, m, c) \in ASSIGNABLE$ plays the role of the two sets $(r, m) \in ELIGIBLE$ and $(m, c) \in TAUGHT$ in the original formulation. This requires additional precomputation to check not only that recruit $r \in R_g$ is eligible for MOS m and MOS m is taught in course c, but also that a student graduating in graduation g has sufficient time after graduation to get to course c. In other words, we must prevent a graduating student from being assigned to a course that takes place before their graduation. The set $ASSIGNABLE$ can be computed easily with the logic in Figure 3.1.

3.2.1 Iteratively Solving for an Entire Year

Formulation M-RDM-22 partitions the overall assignment over an entire FY into $|G|$ subproblems, each with their own MOS targets $target_{m,g}$. Most simply, these can be solved iteratively using the following process.

```
For g in {1, 2, ..., 36}:
    obtain MOS targets target_mg
    solve M-RDM-22
    update residual avail_c capacity limits based on assignments
```

In the situation where the targets $target_{m,g}$ are made available only near the graduation date for graduation class g, this type of iterative solve might be the only option for recruit assignment. The assignment problems for each graduation class share the capacity limits $avail_c$ for course offerings but are otherwise independent.

3.2.2 A Fiscal Year Solve with Per-Class Graduation Targets

If the targets $target_{m,g}$ are known in advance, the assignment across all graduation classes can be solved collectively as follows.

```
create empty ELIGIBLE set
create empty TAUGHT set
create empty ASSIGNABLE set
for all r in set of all recruits in FY accession cohort:
  for all m in set of MOSs in FY ACP:
    if r meets all eligibility requirements for m:
      append (r,m) to ELIGIBLE
      for all c in set of entry-level course offerings:
        if m is taught at course offering c:
          append (m,c) to TAUGHT
          g = MCRD grad date of r
          if m in set of infantry MOSs:
            d = 10+2
          else:
            d = 10+2+29+2 (see caption)
          if (report date for c) >= g+d and (report date for c) < g+d+365:
            append (r,m,c) to ASSIGNABLE
```

Figure 3.1. Pseudocode for calculation of ASSIGNABLE set. The parameter d is the number of required days delay after graduation for a recruit to be able to arrive to a course. If the recruit is infantry, then the "boot leave" is only 10 days plus two days of travel prior to MOS training at SOI. Otherwise, the minimum number of days for "boot leave" includes Marine Combat Training (MCT), a 29-day course of instruction about basic infantry and field skills taught at the SOIs, plus two additional travel days. When looking ahead to potential ASSIGNABLE courses, we consider courses in the next two FYs.

Formulation M-RDM-22a

$$\min_{\substack{X\\SHORT\\OVER}} \sum_{g\in G}\Bigg[\sum_{\substack{(r,m,c)\in ASSIGNABLE:\\ r\in R_g}} X_{r,m,c}(\lambda_{MAT}\, MAT_{r,c} - \lambda_{goodfit}\, gf_{r,m}) + \sum_{m}(\lambda_m^{shortfall}\, SHORT_{m,g} + \lambda_m^{overage}\, OVER_{m,g})\Bigg] \quad (3.13)$$

$$\text{s.t.} \qquad (3.8) - (3.12)$$

Again, the assignment problems for each graduation class share the capacity limits $avail_c$

for course offerings but are otherwise independent.

3.2.3 A Fiscal Year Solve with Annual Targets

The previous formulation (Equation 3.13) partitions the overall assignment over an entire FY into $|G|$ subproblems, each with their own MOS targets. Such a formulation will work adequately provided that the parameters $target_{m,g}$ are available, appropriately separate the overall annual target values for each MOS into individual targets, and are actually achievable. One of the benefits of this approach is that it allows the model to update remaining MOS production requirements and course availability information between class runs. However, this formulation does not allow for zero-sum fluctuations across different graduations. For example, a shortfall in graduating class g does not create any incentive for a compensating overage in graduating class $g + 1$. Rather both missed targets are penalized. Thus, there is no additional incentive to reach an overall target value for an entire year. We propose the following additional formulation to overcome this deficiency.

Additional Data

$fy\_class\_target_m$	The target number of recruits to classify into MOS m over the course of the FY in order to account for expected SOI and MOS school attrition and still meet the MPP-specified production target for fully trained Marines in MOS m within the cohort

Additional Decision Variables

$FYSHORT_m$	Number of recruits classified below $fy\_class\_target_m$
$FYOVER_m$	Number of recruits classified above $fy\_class\_target_m$

Formulation M-RDM-22b

$$\min_{\substack{X\\FYSHORT\\FYOVER}} \sum_{g\in G}\left[\sum_{\substack{(r,m,c)\in ASSIGNABLE:\\ r\in R_g}} X_{r,m,c}(\lambda_{MAT}\; MAT_{r,c} - \lambda_{goodfit}\; gf_{r,m})\right] + \sum_{m}(\lambda_m^{shortfall}\; FYSHORT_m + \lambda_m^{overage}\; FYOVER_m) \tag{3.14}$$

s.t. (3.8) − (3.9)

$$\sum_{(r,m,c)\in ASSIGNABLE} X_{r,m,c} = \Big[fy\_class\_target_m - FYSHORT_m + FYOVER_m \Big] \qquad \forall m \in M \tag{3.15}$$

$$X_{r,m,c} \in \{0,1\} \qquad \forall (r,m,c) \in ASSIGNABLE \tag{3.16}$$

$$FYSHORT_m, FYOVER_m \geq 0 \qquad \forall (m,g) \in M \times G \tag{3.17}$$

Discussion

This formulation is largely the same, but with the variables $FYSHORT_m$ taking the place of $SHORTAGE_{m,g}$ and variables $FYOVER_m$ taking the place of $OVERAGE_{m,g}$. Constraint (3.15) takes the place of (3.10) to set these elastic variables.

This formulation requires specification of annual $fy\_class\_target_m$ values, which might be easier to generate than per-graduation targets $target_{m,g}$.

We also note that both M-RDM-22-a and M-RDM-22-b can be solved iteratively as a *cascade* (see Guthrie 2017, for a general description). That is, we solve for $G = \{1, 2, \ldots, 36\}$ and lock in a solution for $g = 1$, then revisit target levels and solve for $G = \{2, 3, \ldots, 36\}$ to lock in the assignment for $g = 2$. Proceeding in this manner allows for the update of target values over the course of the year as needs change and/or uncertainty resolves.

3.3 Additional Parameter Updates and Coding Corrections

We propose additional updates to the parameters fed into M-RDM that address existing shortfalls in (1) default coefficients, and (2) a desire to incorporate recruit interests in GoF calculations. We also implemented corrections to how goodness-of-fit calculations and swimming qualification eligibility check were coded.

3.3.1 Recommended Prioritization of Objective Function Attributes in M-RDM

Not all of the included metrics and variables ($MAT_{r,c}$, $gf_{r,m}$, $SHORTFALL_m$, and $OVERAGE_m$) in the M-RDM's objective function are considered to be equal in the eyes of the Marine Corps. There is a common saying in the Marines Corps, "Mission first. Marines always," which is taken to mean that the needs of the Marine Corps and the nation will always come first, followed by the needs of the individual Marine. This saying implies that likely we should be applying at least equal or greater emphasis on minimizing our total number of MOS shortfalls than we do on any of the other metrics or variables, because, at least in the near term, the MAT and GoF metrics seem predominately based around Marine welfare rather than mission accomplishment and because the $OVERAGE$ variable does not directly affect mission accomplishment or Marine welfare. We qualify the previous statement with, "at least in the near term," because the Commandant acknowledges that "A Marine Corps that matches Marines' talents to their duties will perform at a higher level in competition and combat" (Berger 2021). Thus we expect we would eventually see improvements in mission performance and meeting the needs of the Marine Corps through improving the GoF of recruit-MOS assignments as well.

However, we do not expect the favorable impact on mission accomplishment from improving GoF to be as immediate and direct as the favorable impact of ensuring that all MCRD graduation ESM-specified MOS targets are met (i.e., that we are reducing our MOS shortfalls). Both the $SHORTFALL$ variable and the GoF metric seem closely related to mission accomplishment, whereas the metric of expected MAT times and the variable of $OVERAGE$ seem less closely related. The $OVERAGE$ term seems the least important to prioritize (penalize), because having an overage in a specific MOS assigned on one model graduation run would reduce the annual requirement for the MOS in future model runs which would not necessarily be a bad thing and would likely push the overall FY assignments closer to the end-of-FY requirement. Creating an MOS overage in an assignment would also already seem to result in an additional MAT penalty in most cases in that more recruits would be assigned to that MOS than were planned to be by the ESM, which took into account the known TECOM course offerings for the year for that MOS when it was run.

Thus we propose the following relative ordering of priorities for the key metrics and variables in the objective function. First, prioritize minimizing MOS shortfalls, which most directly meets the immediate needs of the Marine Corps. Second, maximize GoF, as this is believed to result in better performance of Marines within their assigned MOSs and in an increased likelihood for them to reenlist down the road. Third, minimize expected MAT time, as this shortens the collective expected STF timeline for the Marines, meaning the Marine Corps has to pay them less during their training timeline when they are not directly contributing to an operating unit. And fourth, minimize MOS overages, because these do not directly adversely affect the Marine Corps for a given model run as the overages, in most graduation runs, likely help satisfy the greater MOS target for the FY and will already be penalized in that they likely result in increased expected MAT time for the over-assigned recruits.

We achieve the recommended prioritization by adjusting each of the objective function coefficient (λ) values to the values in Table 3.1, as opposed to their default values which are all one.

MOI or Variable	Desired Pri.	Approx. Mag. of Units per Coast Grad	Recmd'd λ
$SHORTFALL_m$	4	(1 recr/MOS)*(100 eligible MOSs)	$\lambda_m^{shortfall} = 4$
$gf_{r,m}$	3	(0.92 GoF/recr)*(300 recr)	$\lambda_{goodfit} = 1.09$
$MAT_{r,c}$	2	(31 days/recr)*(300 recr)	$\lambda_{MAT} = 0.02$
$OVERAGE_m$	1	(1 recr/MOS)*(100 eligible MOSs)	$\lambda_m^{overage} = 1$

Table 3.1. Recommended default M-RDM λ coefficients.

3.3.2 Alternate Goodness of Fit Formulation Including Interest Values

While recruit ASVAB scores help measure appropriate aptitude for potential MOSs, as alluded to previously in this work and by the Commandant in *Talent Management 2030*, the interest that a recruit has for a specific MOS will also likely impact their future job performance in that MOS. Thus, we should consider an alternate, and more holistic, formulation of GoF as follows in Equation 3.18.

$$gf\_alt_{r,m} = \lambda_{int} \cdot int_{r,m} + \lambda_{apt} \cdot \left(\frac{\sum_{s \in ASVAB_m} (1 - \frac{|recruit\_score_{r,s} - target\_score_{s,m}|}{target\_score_{s,m}})}{|ASVAB_m|} - 0.9 \right) \tag{3.18}$$

where $int_{r,m}$ would be additionally required data, and λ_{int} and λ_{apt} would be additionally required user-defined parameters, described below.

This alternate GoF formulation would allow the model users at MMIB to adjust the λ_{int} and λ_{apt} parameters to affect the relative prioritization of recruit interest versus recruit aptitude for their selected MOS. The recommended defaults for these parameters should be a value of one for λ_{int} and a value of ten for λ_{apt}, if attempting to prioritize both aspects (interest and aptitude) evenly. This is because we expect the input data for $int_{r,m}$ to vary from zero to one, whereas we know the GoF scores resulting from Equation 3.20 tend to produce values that vary over only about one tenth of that range (from about 0.9 to 1.0), since all minimally qualified recruits would have a minimum GoF of 0.9090909 (repeating). After shifting this expected range to the left by 0.9 in Equation 3.18 it should become roughly 0.0 to 0.1. Then multiplying this range by ten puts it on a relatively level playing field with the expected interest scores, with expected values from zero to one. This yields Equation 3.19, the form in which both the interest and aptitude scores (compared to the 110% target) are each standardized from zero to one.

$$gf\_alt\_std_{r,m} = int_{r,m} + 10 \cdot \left(\frac{\sum_{s \in ASVAB_m} (1 - \frac{|recruit\_score_{r,s} - target\_score_{s,m}|}{target\_score_{s,m}})}{|ASVAB_m|} - 0.9 \right) \tag{3.19}$$

Note that we would expect the range of these $gf\_alt\_std_{r,m}$ scores to vary from zero to two, not from zero to one as we expect of $gf\_std_{r,m}$ scores (see below).

3.3.3 Corrected Parameter Calculations

While reviewing the M-RDM implementation from Martinez (2021), we noted three places where the code required correction.

Goodness of Fit Calculation within M-RDM Code. While reviewing the M-RDM Python script, we noticed that the $gf_{r,m}$ was not actually being calculated as in Martinez (2021), which describes the 110% goodness of fit calculation as follows in Equation 3.20.

$$gf_{r,m} = \frac{\sum_{s \in ASVAB_m} \left(1 - \frac{|recruit\_score_{r,s} - target\_score_{s,m}|}{target\_score_{s,m}}\right)}{|ASVAB_m|} \tag{3.20}$$

Note that the use of the vertical bars in the denominator of Equation 3.20 refers to the cardinality of the set of ASVAB skills with prescribed minimums for MOS m, whereas the use of vertical bars in the numerator refers to the absolute value of the difference between a recruit's score in a specific skill and the "ideal" 110% target score for that skill in the MOS.

Equation 3.20 prescribes that the recruit's goodness of fit with an MOS will be determined based on the flat average of their goodness of fit scores (by the 110% ASVAB aptitude standard) across all the required ASVAB categories with minimums specified for that MOS (i.e.,with no one ASVAB area score being weighted more highly than another).

Despite what this equation states, we found that in the actual M-RDM Python script there was a subtle difference in how the $gf_{r,m}$ scores were actually being calculated. This difference was undetectable in the case of calculating GoF scores for MOSs that had only one or two skills with defined ASVAB minimum scores, but had an effect on MOSs with three or more skills with required ASVAB minimums.

The relative impact of this existing error on the FY21 recruits that Captain Martinez analyzed in his thesis would have been very small. Only one MOS, MOS 2146 (Heavy Ordnance Vehicle Repairer/Technician), appears to have had three or more ASVAB skills with required minimum scores listed in the requirements document he was using. These skills were in the electrical category (EL), mechanical maintenance category (MM), and general technical category (GT) skills for that MOS and would have appeared in that order in the erroneous GoF calculations between recruits and MOS 2146. This would have resulted in the GT skill-specific GoF score being weighted twice as much as each of the EL and MM skill-specific GoF scores in the overall recruit-to-MOS GoF score calculations for MOS 2146 for all recruits.

By comparison, this error would have no impact on the FY19 accession cohort recruits. This is because, of the 146 different MOSs with production requirements specified in the FY19 ACP and ASVAB skill minimum requirements specified in the FY19 PEF offerings, zero of them have three or more skills with required minimums. Regardless of the lack of impact for FY19, the error is still worth fixing to ensure that the model will work properly for all future FYs for which any number of MOSs could become more selective and require three or more ASVAB skills to have specified minimums. This seems particularly likely in light of the need to field a smaller but more capable and mature force of Marines to win in the expected future EABO environment.

Corrected Swimming Qualification Eligibility Check. We similarly found a small typo in the calculation of the swimming eligibility check. The typo in the original code was only a single character but meant that no required swimming qualification check of any sort was being performed for MOSs with advanced swimming qualification (level "A") requirements.

Marine Combat Standards Eligibility within M-RDM Code. Finally, while not yet in common use, the M-RDM code contains the capability to include Marine combat standards (MCS) eligibility checks on specific recruits for specific combat arms MOSs, but we found a couple of errors in these checks, which we fixed. When it came to determining a recruit's eligibility based on both their “movement-to-contact” and “maneuver-under-fire” times, the recruits were determined to be failures if they scored times less than or equal to the specified threshold, when in reality for these time-based events you fail when you exceed the threshold. Thus we reversed the direction of the inequality check and excluded the passing threshold scores to fix the determination of failing times in these events. In the future, if the MCRDs can send the latest recruit scores in these various physical fitness events to the M-RDM monitor before they run the model, then these MCS checks can now correctly be incorporated in future model runs.

3.4 Methodology for Model Comparison

In this section we specifically describe the methodology that we use to compare the RDM and various M-RDM results for the FY19 recruit assignments that were made, and would have been made, respectively.

3.4.1 Comparing FY MOS Shortfalls

In order to determine which model better fills the immediate FY MOS production requirements of the Marine Corps, we consider which model comes closer to meeting the FY19 $fy\_class\_target_m$ for each MOS as defined above. It is important to remember that this number for each MOS is not the same as the total Marine Corps production requirement for that FY accession cohort specified in the FY ACP, but rather reflects those numbers after they have been inflated by the ESM to account for expected attrition across all entry-level training following MCRD. This is why we refer to this quantity as the FY19 classification target number for the MOS within the accession cohort, to distinguish it from the production requirement for the MOS.

As a primary metric for model comparison in this area we will use Equations 3.21 and 3.22.

$$FYSHORT_m = max(0, fy\_class\_target_m - \sum_{r,c:(r,m,c)\in ASSIGNABLE} X_{r,m,c}) \tag{3.21}$$

$$FYSHORT_{model} = \sum_{m} FYSHORT_m \tag{3.22}$$

3.4.2 Comparing Recruit "Goodness of Fit"

For the second major comparison we will consider the GoF using the 110% ideal aptitude standard described in Equation 3.20 above. Recognizing that almost all of these values are between 0.9 and 1, we approximately normalize them from 0 to 1 (by subtracting 0.9 from all the values and multiplying them by 10) as follows in Equation 3.23:

$$gf\_std_{r,m} = 10 \cdot (gf_{r,m} - 0.9). \tag{3.23}$$

Then we aggregate these values for all recruit-MOS assignments as a simple sum as described in Equation 3.24:

$$fy\_gf = \sum_{(r,m,c) \in ASSIGNABLE} gf\_std_{r,m} X_{r,m,c} \tag{3.24}$$

As well as considering the overall summation of the standardized GoF scores for each recruit, we will examine the distribution of the GoF scores to determine whether any noticeable differences between the results of the two models emerge.

3.4.3 Comparing Expected MAT Time

For the final major metric of comparison we will examine the expected MAT time for all recruit-to-MOS assignments that were made over the course of the FY by each model. For this we sum the expected MAT accrued across all the recruit-to-course offering assignments that were made over the course of the FY as shown in Equation 3.25:

$$fy\_MAT = \sum_{(r,m,c)\in ASSIGNABLE} MAT_{r,c} X_{r,m,c} \tag{3.25}$$

In addition to the overall summation of the expected MAT times associated with the assignments we are interested in examining the distribution of expected MAT times and any significant outliers and trends associated with each model.

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CHAPTER 4: Model Results for Fiscal Year 2019

This chapter compares the assignments the baseline RDM made in FY19 to the assignments the M-RDM-22 would have made in its current state, and using its newly-proposed coefficients. First, we review the input data to the model and provide a brief introduction to the major differences between the assignments made by the two models. After thus setting stage, we compare the recruit-to-MOS-and-course-offering assignments in terms of their end-of-FY-accession-cohort MOS classification shortfalls, their recruit-to-MOS standardized GoF scores, and their recruit-to-course-offering expected MAT times. Last, we provide an additional analysis of recruit days lost due to multiple assignments made to specific recruits by the RDM, which was not a factor with the M-RDM-22 assignments.

4.1 Model Inputs

Our model input is 20,720 recruits spread across 36 historical MCRD graduation classes that comprise the FY19 accession cohort. For each recruit, we have personnel data (as summarized in the left side of Figure 2.5) at the time they are ready to be classified. In addition, we start with 2,114 separate historical course offerings with (non-zero) availability as being available to these recruits. These courses had an average of 15.58 available seats per course offering.

The model also takes as input the MOS classification target numbers for each of the 146 PMOSs within each of the 36 graduation classes. Unfortunately the historical target numbers used in FY19 were not available, so these target values had to be generated from the aforementioned manpower model the ESM. However, the ESM was first developed in FY20, thus requiring that we make several assumptions to get that model to work for FY19. Specifically, we select a subset of historical FY18-FY21 course offerings from the official MCTIMS roster that seemingly correspond to initial entry-level "first CID" course offerings for each PMOS according to the same MOS-to-CID mapper file that was used by the ESM in FY20. The ESM also relies on historical assumptions about the ratio of each gender within each rank and MOS, so that it sends to each MCRD a number of "shippees" by gender and selected MOS that can be properly accommodated. The ESM outputs also rely on assumptions about MCRD and post-MCRD attrition rates for each MOS according to the associated primary PEF, so that the number of "shippees" generated could be appropriately increased to plan to meet the associated end-of-FY PMOS production requirements. And lastly, the ESM relies on an assumption that the MCRD capacities are unconstrained (i.e., that the number of "shippees" generated at one time would never exceed the capacities of the depots to accommodate them).

Because the "shippee" schedule produced by the ESM is currently the primary basis for generating the per-MCRD graduation class MOS classification targets for the M-RDM, we opt to use the same historical four-year MCTIMS course offering roster (used to produce those ESM-generated targets) to determine the master course offering availability roster within the M-RDM as well.

4.2 Comparison of MOS Assignments

The first thing we compare is the overall number of recruits classified into different MOSs. Of the 20,720 recruits, the RDM classified 20,092 different recruits into MOSs and left a total of 648 different recruits unassigned on various model runs, an average of 18 on each of the 36 grad class model runs in the FY. By comparison, the M-RDM-22 classified all 20,720 unique recruits into MOSs, but 4,806 of those were into a "dummy" MOS created to ensure model feasibility. Thus, for practical purposes it is fair to say that the M-RDM-22 assigned 15,914 recruits to MOSs but left 4,806 unassigned.

Next we consider the number of assignments that adhered to minimum ASVAB eligibility standards (defined by the minimum standards of any PEF associated with the assigned MOS). In FY19, the RDM and its human model user (monitor) were responsible for assigning 1,895 recruits into MOSs for which they did not meet the minimum ASVAB requirements in at least one skill area. In contrast, the M-RDM-22 assigned zero recruits into MOSs that they did not meet all minimum ASVAB requirements for; this is by construction.

Discussion of "Dummy" Assignments

The M-RDM-22 classified 4,806 recruits into a made-up "dummy" MOS that exists to ensure model feasibility. Here, we briefly consider the question: *why so many "dummy"* *assignments?*

We are confident the objective function penalties associated with “dummy” assignments are sufficiently high (accruing a MAT time of 999,999 days and a GoF penalty of -10000) to ensure that an optimal solution would include them only if no other feasible assignment was possible.

One possibility considered was that many of these recruits did not meet the minimum requirements for any MOS. However, it is clear that all such ineligible recruits were filtered out from their recruit class data sets prior to running any iterations of the model. Specifically, we found 1,800 recruits that were found completely unqualified and set aside from the 20,780 before being fed into either model.

The other possibility is that there was a lack of available seats in CID course offerings. Specifically, if the solver is unable to find available seats in any appropriate “first CID” course for all the possible MOSs for which each given recruit would have been qualified, it has no choice other than to assign them to the “dummy” MOS. We believe that this is the case and these dummy assignments were the result of a lack of available and appropriate “first CID” seats on the course offering roster that the M-RDM was considering. However, due to a lack of time, this conjecture has not been investigated thoroughly.

Discussion of Required Human Effort

Finally, we consider the amount of “human model-user time” required by each model. The RDM required roughly a full work year each from a billet-coded gunnery sergeant “RDM Monitor” and staff sergeant “Reclassification Monitor” to produce 1,162 necessary manual monitor assignments and then to work the necessary follow-on reclassifications for those that needed to be multiply assigned. The M-RDM-22 on the other hand, conducted the year’s worth of recruit classifications in about six hours (after several days of data collection and consolidation) with no active human supervision required after initiation, on a personal laptop using an Intel Core i7, 10th generation processor, albeit probably with much less personal touch.

However, we must again consider the 4,806 “dummy” classifications here which essentially amount to unassigned Marines that would still require manual monitor attention if they cannot be resolved to be fewer in number in future iterations of the model. As a result, the actual time savings are potentially less than the difference noted above.

4.3 Comparison of MOS Classification Shortfalls

Next we compare MOS classification shortfalls for each model. We separate the 146 primary MOSs into fifths so that each may be readable across the horizontal axes of individual plots. Figures 4.1-4.5 illustrate.

In each figure, a blue line tracks the annual end-of-FY-accession-cohort classification target for each MOS. These classification targets are determined based on the production requirements for each MOS, as specified in FY19 ACP, which are then increased to account for expected post-MCRD attrition rates for each MOS prior to finishing their entry-level training pipeline.

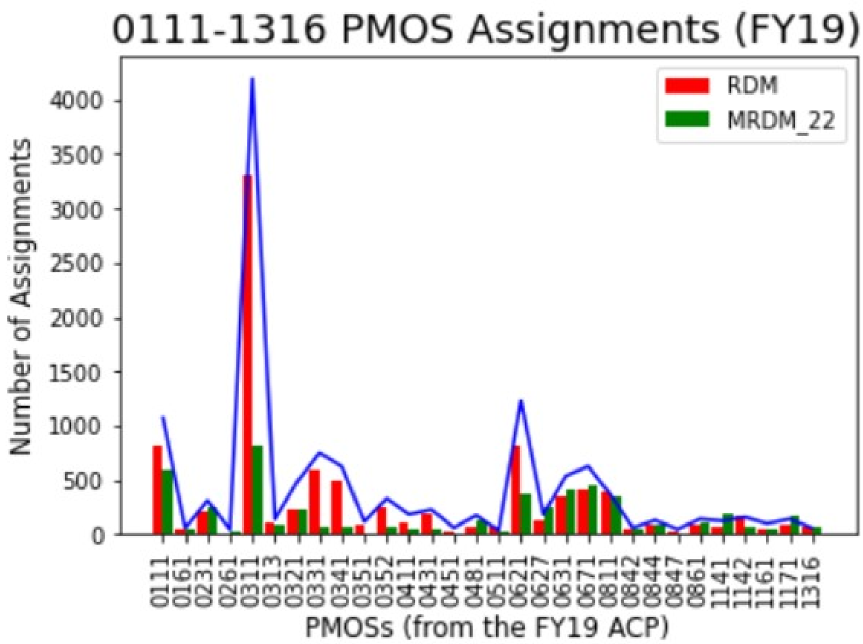

Figure 4.1. A comparison of 0111-1316 PMOS assignments for FY19. The blue line represents the target values for each PMOS.

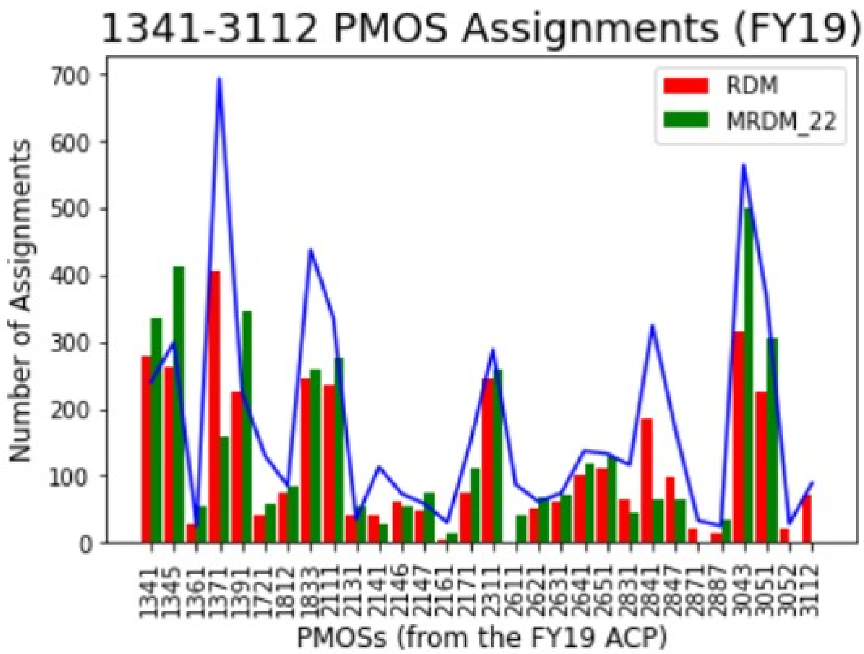

Figure 4.2. A comparison of 1341-3112 PMOS assignments for FY19. The blue line represents the target values for each PMOS.

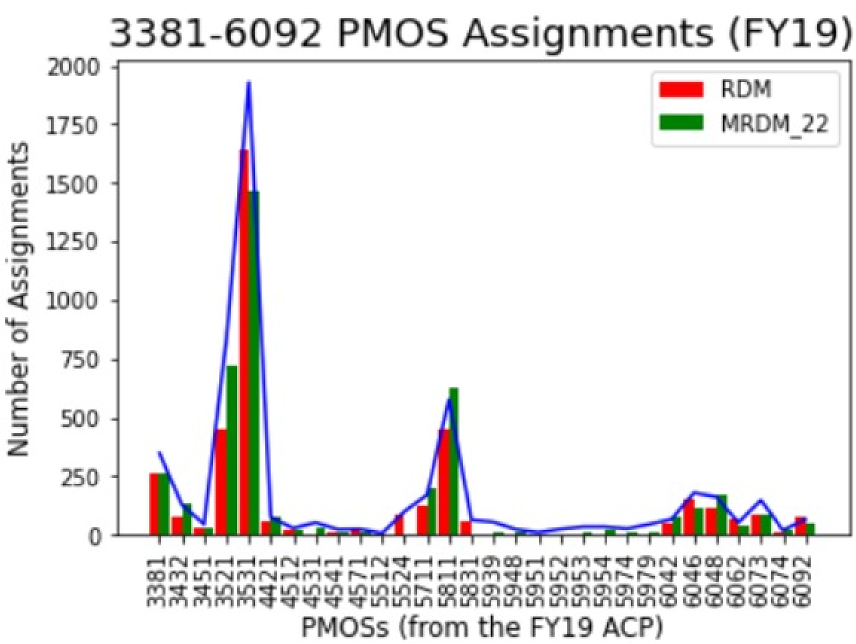

Figure 4.3. A comparison of 3381-6092 PMOS assignments for FY19. The blue line represents the target values for each PMOS.

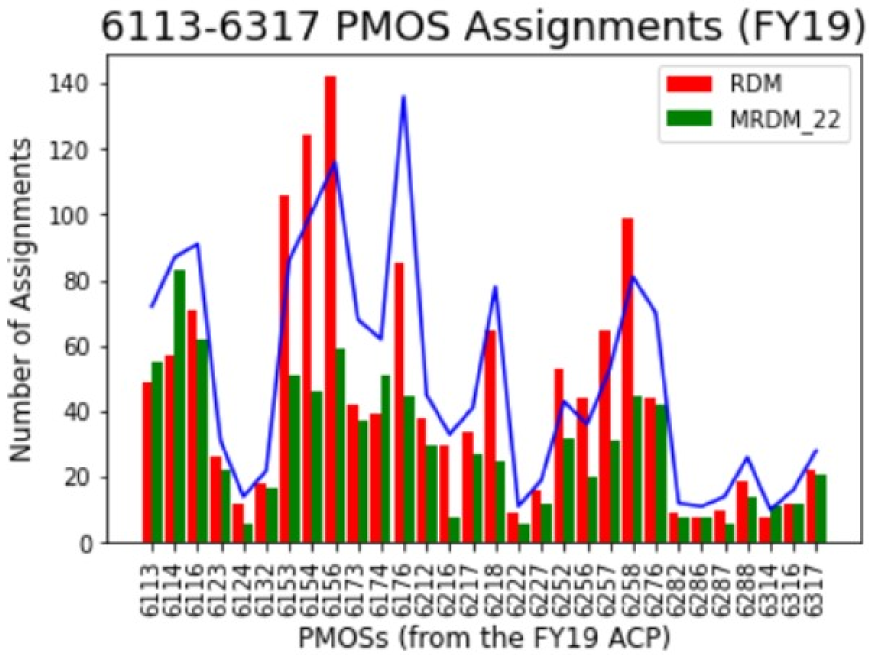

Figure 4.4. A comparison of 6113-6317 PMOS assignments for FY19. The blue line represents the target values for each PMOS.

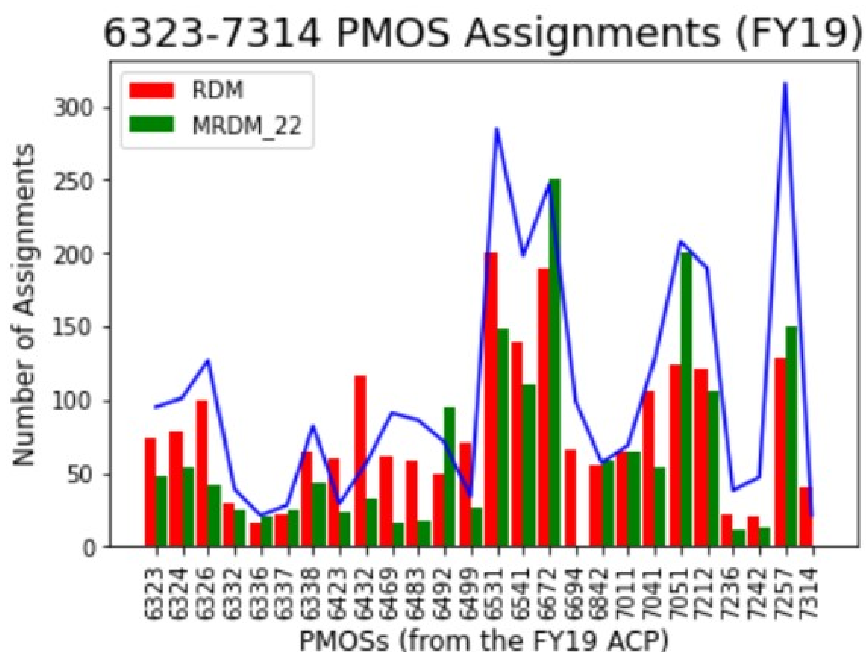

Figure 4.5. A comparison of 6323-7314 PMOS assignments for FY19. The blue line represents the target values for each PMOS.

For PMOSs 0111-3112 (Figures 4.1 and 4.2), we note that the M-RDM-22 under-classified recruits into a number of infantry (03XX) MOSs as well as MOSs 0621 (Transmissions System Operator), 1371 (Combat Engineer), and MOS 2841 (Ground Electronics Transmission Systems Maintainer) when compared to its historical RDM counterpart. We expect these differences are due to differences that existed in the historical MCTIMS course offering roster that was used by the M-RDM-22 in terms of both the non-existence of certain courses that the RDM assigned personnel to and in terms of the numbers of seats that were available to assign personnel to within those courses that did exist on both the historical RDM quotas record and on the MCTIMS course offering roster. It is not expected that the M-RDM-22 has any inherent bias otherwise against making assignments in such areas.

For PMOSs 3381-6317 (Figures 4.3 and 4.4), we note that in the 3381-6092 range of PMOS assignments, the M-RDM-22 slightly out-performed the historical RDM assignments in terms of meeting the FY classification targets, or at least it seems to have performed as well as the RDM across these MOSs, excepting perhaps MOSs 5524 and 5831. This, despite its 4,806 "dummy" assignments across the board. Across the 6113-6317 range of the PMOSs though we again see M-RDM-22 under-classification across a wide band of relatively low-density aviation-related PMOSs in the mid-6100s to mid-6200s range. We again expect that these shortfalls are due to the M-RDM-22 having not had access to the exact same course offering roster as the RDM at the time it was executed.

For assignments to PMOSs 6323-7314 made by the two models in Figure 4.5, we see the M-RDM-22 winning out on a handful of MOSs, but otherwise being marginally bested in about two-thirds of the PMOSs by the historical RDM results.

Summing up the total MOS classification shortfalls, we have $FYSHORT_{RDM} = 7,788$ and $FYSHORT_{MRDM-22} = 12,520$. Here, we must again consider that the 4,806 "dummy" assignments were not included in any of these PMOSs and thus they have contributed significantly to the difference in the total number of fiscal year shortfalls between the two models.

Perhaps we should not be surprised by the RDM results in the area of total end-of-FY classification shortages seemingly besting the M-RDM-22 with default parameters when we consider that the existing RDM is really only a single objective optimization function and the M-RDM considers other optimization objectives in its formulation as well. The impacts of these other considerations can best be seen in the following sections.

4.4 Comparison of "Goodness of Fit" Scores

Next we compare the GoF metric as described in Equation 3.20. The RDM assignments achieve an average GoF of 0.9184 with a median of 0.9339, whereas the M-RDM assignments (with the "dummy" assignments removed) achieve an average GoF of 0.9317 with a median of 0.9422. Figure 4.6 provides a side-by-side comparison of the entire distribution of GoF values for each model's assignments.

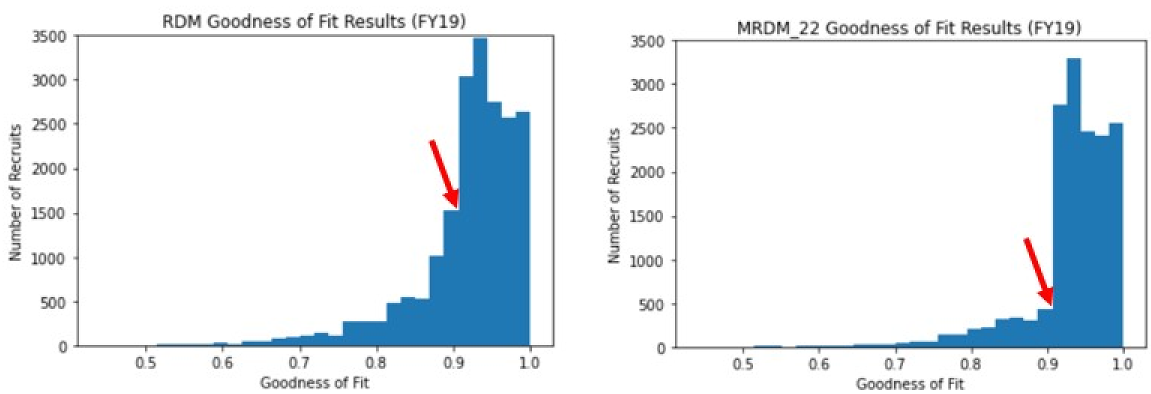

Figure 4.6. Comparison of "goodness of fit" results for FY19 assignments. There are no under-qualified recruits affecting GoF for the M-RDM.

While at first seemingly similar in shape, a closer look reveals a sharper "elbow" in the histogram for M-RDM assignments (on the right of Figure 4.6) which occurs at a GoF of approximately 0.91. This occurs because the GoF cut-off for a minimally ASVAB-qualified Marine in all areas is 10/11, or approximately 0.90909, which is an artifact of how GoF was originally defined by Captain Martinez shown in Equation 3.20.

The distribution mass we see to the left of the 0.90909 mark on both histograms can generally be the result of either overqualified or under-qualified recruits, or both, for the MOS they are assigned. In the case of the RDM specifically, where we know there were 1895 under-qualified assignments made by that model, the mass we see to the left of 0.90909 on the left histogram is clearly the result of both. By contrast, in the case of the M-RDM-22 (the histogram on the right) we know that all the mass to the left of 0.90909 is exclusively the result of exceptionally overqualified recruits, because we have verified in the resulting assignments that the M-RDM-22 classified zero recruits below their required ASVAB MOS standards.

After standardizing all the depicted recruit GoF scores through the function shown in Equation 3.23 and after aggregating them all across all the recruits that were assigned in the FY, as shown in Equation 3.24 we arrive at a $fy\_gf_{RDM} = 3703$ and a $fy\_gf_{MRDM-22} = 5050$. This indicates that the cumulative results of the GoF scores for the M-RDM-22 were roughly 50/37 better than those of the RDM, by our chosen metric. If graphed, the chosen metric results in a shifting to the left (by 0.9) and then horizontal stretching (dilation) of the histograms by a factor of ten within which the vertical (right) part of the histogram then appears in the range from zero to one, and the tail (left) portion of the resulting histograms extends down to about negative four. When this metric is then aggregated across all recruit assignments, it has the effect that GoF scores that were originally less than 0.9 end up becoming negative and having a deleterious effect on the overall sum, whereas GoF scores that were originally greater than 0.9 end up being positive and having an additive effect on the overall sum.

4.5 Comparison of Expected MAT Times

Next we compare the expected MAT time of the two models. Here, the M-RDM-22 results appear much improved over those of the RDM. The differences in MAT time experienced by the recruits are readily apparent when looking at the distributions of MAT values for each model in Figure 4.7.

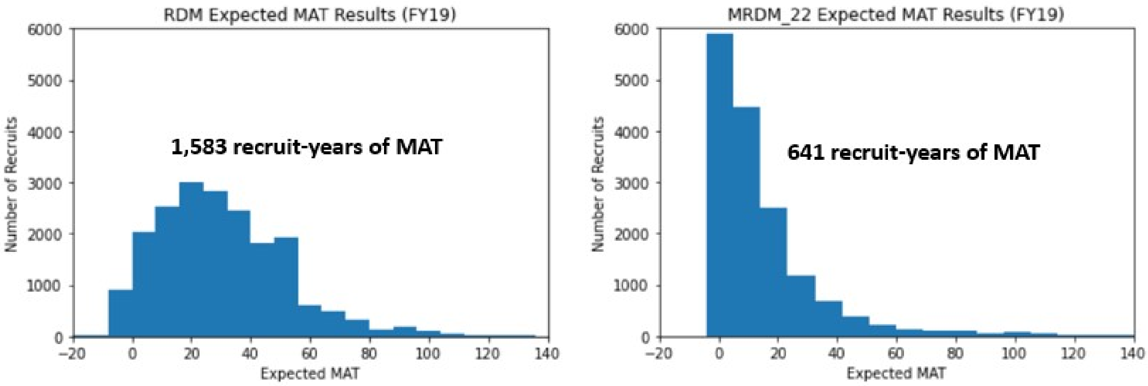

Figure 4.7. MAT Comparison in FY19.

First, regarding the shapes of the distributions, we note the stark differences. Figure 4.7 reveals a monotonically decreasing distribution of expected MAT times for the M-RDM-22 resulting in only 641 recruit-years of MAT time for the 15,914 recruits classified into "non-dummy" MOSs. In contrast, the RDM yields a total of 1,583 recruit-years for the 20,092 assignments that the RDM made. Per recruit, this amounted to an average expected MAT time of 14.7 days for the M-RDM-22 and 28.8 days for the RDM. *If these per-recruit savings between models of 14.1 days per recruit had been applied to all the 15,914 recruits that were classed by the simulated M-RDM model run in FY19, the difference would have amounted to about 615 recruit-years!*

To give a sense of the potential savings there, conservatively assuming that every recruit during this time remains a private with fewer than four months of service (though some of them will surely exceed these thresholds and get pay increases during their MAT period), and using the additionally low "base pay" measure of $1555 per month (Navy CyberSpace 2022), we can conclude that these 615 recruit-years could potentially have saved the Marine Corps $11,475,900 in FY19 for recruit base pay alone. And if you consider that a private typically makes more in combined non-taxable allowances (including basic allowances for housing, subsistence, and clothing) than they do from their base pay (Military OneSource 2022), and the additional monetary benefits these recruits receive in terms of both military family health insurance and retirement benefits, then you could quickly see the estimated the monetary savings to the Marine Corps of this MAT time reduction as exceeding $25 million for the FY19 accession cohort alone.

The differences in MAT savings are not surprising. The RDM uses expected MAT only as a tie-breaker to determine recruit MOS assignment, whereas the M-RDM considers MAT a primary objective worth consideration in the objective function of the model formulation.

It is worth noting the RDM shows a few cases of making assignments that resulted in expected MAT times of -10 or less. After looking into these cases, these were in fact cases where the RDM or its human monitor assigned a recruit to an IMOS and initial course offering that precluded them from exercising their 10 days of supposedly guaranteed “boot leave” immediately after graduating from MCRD. The M-RDM-22 currently, by design, does not have the ability to make assignments such as this and guarantees that all recruits will receive their allotted 10 days of “boot leave” before they are considered eligible to attend any initial entry-level course offerings. If TECOM decides to modify the allotted “boot leave” window, it will only require a few minutes to implement that update within the model.

4.6 Recruit Days Lost Due to Multiple RDM Assignments

After aggregating all of the assignments made by the RDM over the course of the FY19 accession cohort it becomes clear that a significant number of recruits had been assigned multiple times by differing model runs. Specifically, 148 recruits received multiple assignments. Four of these recruits had three different assignments each made to them over the course of the FY, and the other 144 recruits had one reassignment made each.

Multiple recruit assignments ultimately results in lost days beyond MAT delays. When looking at the historical RDM assignments, it is clear that something went wrong with the model or the monitor in almost all cases, as they assigned the recruits to MOS and initial course offerings which were infeasible for them to attend. From conversations with the current RDM monitor at MMIB, in most cases the need for a reclassification is not caught until the recruit arrives at the course offering they believe they will attend (McGhee 2022b). Circumstances such as these result not only in lost recruit-days, but in additional travel costs too. Further, it almost certainly contributes to a loss of morale and/or momentum in the budding career of the recruit. This is quite the opposite of the way Marines are supposed to treat their newest Marines as outlined by the former commandant General James Amos in Marine Corps Reference Publication (MCRP) 6-11D, *Sustaining the Transformation*

(United States Marine Corps 2014).

A visual understanding of the impact of these multiple RDM assignments on the new Marine recruits in FY19 can be seen in Figure 4.8.

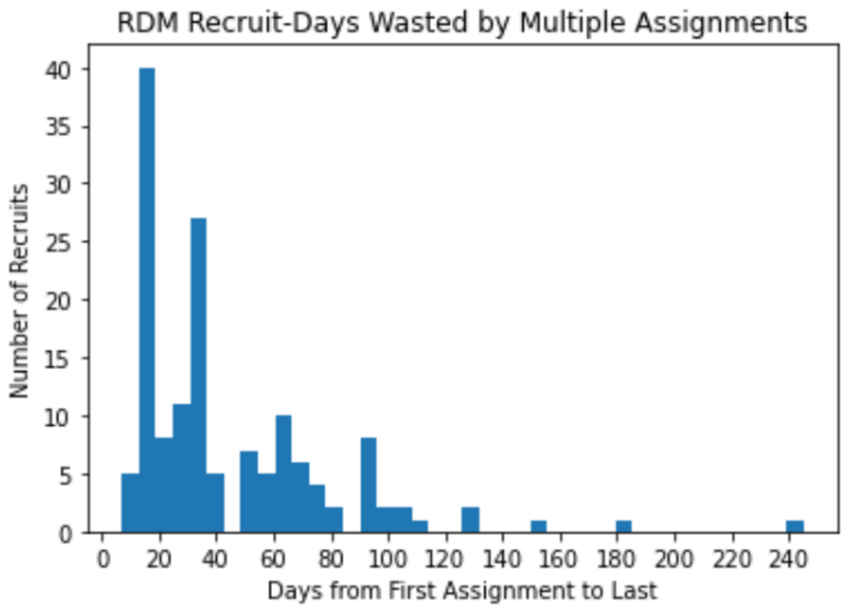

Figure 4.8. RDM recruit-days wasted by multiple assignments.

When aggregated, all of the RDM reclassifications shown in Figure 4.8 resulted in 6,454 lost recruit days or about 17.68 recruit-years, with an average of 43.6 and a median of 35 lost days per recruit. Using the same conservative pay estimates as above in Section 4.5, we can conclude that these 17.68 recruit-years lost the Marine Corps at least $329,949 dollars in FY19 for recruit base pay alone. And if you consider the same additional allowances and monetary entitlements, then you could quickly see the monetary loss to the Marine Corps of these recruit reclassifications to have exceeded three quarters of a million dollars for the FY19 accession cohort alone.

CHAPTER 5: Summary and Conclusion

This chapter summarizes the key works of this thesis, concludes with a recommendation for the future use of both models, and creates a list of recommended future work.

5.1 Summary

The task of making initial recruit MOS and course assignments over the course of an entire FY is not trivial. The current Marine Corps RDM lacks some of the functionality and flexibility to address the changing needs of M&RA, and the recently developed M-RDM is positioned as a possible upgrade and replacement.

The goal of this thesis is to provide a side-by-side comparison of the performance of the RDM with that of the proposed M-RDM over an entire historical fiscal year of recruit assignments. Doing so required that we pull together information on recruits, MOS classification targets by MCRD class, and historical course offerings most notably. It also required that we aggregate information on annual PMOS production requirements, expected MCRD and post-MCRD recruit attrition rates by MOS, specific linkages between intended PMOSs and the appropriate "first CIDs" in their intended training pipelines, as well as databases of PEF eligibility requirements and listings of the included PMOSs for each PEF. Only some of this information was actually available for our intended fiscal year 2019 accession cohort of interest, and a great deal of the rest had to be generated from current documents with numerous assumptions made along the way.

The result was an imperfect comparison between the outputs of the two models. Specifically, the M-RDM assigned a significant number of the overall Marines to a "dummy" MOS that was created for cases where other assignments were not feasible. Despite this hiccup, the results still seem to indicate the relative strengths and weaknesses of the two compared models across the main three metrics of interest. The RDM, not surprisingly, performs very well in the area of minimizing MOS overall annual classification shortfalls, as that is really the single main objective of its formulation. The M-RDM-22 by contrast, performs much better in the areas of both GoF and the expected MAT time of the assignments it makes, as it gives each of those tenets significant consideration in its object function, just behind what it gives to MOS shortfalls.

5.2 Conclusion

Although still a bit premature until some more model testing can be performed, we speculate that the M-RDM will be able to produce the same results as the RDM in future FYs if desired, by weighting it exclusively to favor reducing MOS shortages. We believe that it will also be able to produce more balanced solutions than the RDM which have the ability to improve other aspects of proper talent management including GoF, expected MAT times, and MOS overages.

Due to its flexibility in these ways and to its ability to solve for a full fiscal year in about 6-8 hours at this time, we recommend the M-RDM continue to be developed and tested as a potential replacement for the RDM.

We are not advocating terminating use of the RDM at this time, but rather the continued exploration and improvement of the M-RDM-22 alongside the employment of the RDM for now.

5.3 Future Work

There remains considerable opportunity for future work in improving initial recruit MOS and course assignments, and in the continued development and testing of the M-RDM-22.

First, continued testing of the M-RDM-22 iterative fiscal year solve type should be conducted. This testing should include wide-ranging sensitivity analysis to the four input lambda value weights to determine the range of responses possible from the model based on set human and training data in a given year.

Second, the M-RDM-22 should be tested alongside the RDM in FY23, with current real-time information on recruits and training courses being incorporated as it becomes available throughout the year. This will enable a better sense of what information is realistically available to the model before the fiscal year starts and from what data storage networks or systems, as well as how the information fidelity can change over the course of the fiscal year that follows.

Next, the M-RDM-22 should be uploaded to the ADVANA/Jupiter software and data analytics environment, for continued development to establish live data links between it and the ODSE, TFDW, MCTIMS and any other personnel or training data repositories that may be needed to effectively run the model with the most up-to-date information possible each time it is run.

Alongside this, continued testing of the ESM and the value of the "master combo" "shippee" schedule that it creates should be conducted. The success of the M-RDM-22 and M-RDM-22a formulations is likely to be bounded by the proper determination of these graduation class MOS classification targets.

Next, we recommend development of additional Python and Pyomo code within the M-RDM script to implement the "M-RDM 2022 Alpha" (M-RDM-22a) and "M-RDM 2022 Bravo" (M-RDM-22b) fiscal year solve types as formulated in Section 3.2. Though the M-RDM-22a formulation in the script will likely be increasingly complex beyond the existing M-RDM-22 (iterative) annual solve type and still be equally reliant on the ESM, we can expect that the M-RDM-22b formulation will actually be considerably easier to formulate, and will not rely on ESM outputs at all. Thus we should prioritize the formulation and implementation in Pyomo of the latter M-RDM-22b solve type over the former, to see how the solutions of that model variation might differ from those we have seen thus far.

Beyond the M-RDM-22a and M-RDM-22b models, we believe there is an opportunity to develop a "cascading" solution for an entire fiscal year, one in which planned assignments over a given planning horizon are repeatedly resolved as additional information becomes available (as in Guthrie 2017).

Finally, if and when the interest scores of potential recruits for each of the various possible PMOSs becomes available (as planned for the MCOSM survey tool), there will be an additional opportunity to provide a much better overall assessment of "goodness of fit" within the model. The current implementation of the M-RDM should make it relatively straightforward to include the required changes.

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APPENDIX

“Basic MOS”: According to the MOS Manual in use in FY19, Basic MOSs are, “Entry-level MOSs required for the P2T2 T/O for entry-level Marines or others not yet qualified by initial skills training. In addition, when a Reserve Component (RC) Marine transfers to a new unit and does not possess the MOS required for the billet filled, he will be assigned a Basic MOS until the completion of required formal school training or is otherwise certified to be MOS qualified” (Department of the Navy 2018, p. xiii).

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